

Size Specific Total Particulate Emission  
Factors for Mobile Sources

Energy and Environmental Analysis, Inc.  
Arlington, VA

Prepared for

Environmental Protection Agency, Ann Arbor, MI

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## Size Specific Total Particulate Emission Factors for Mobile Sources

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NATIONAL TECHNICAL  
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SPRINGFIELD, VA. 22161

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# **Size Specific Total Particulate Emission Factors for Mobile Sources**

by

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Contract No. 68-03-1865  
Work Assignment 1

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August 1985

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## 1. INTRODUCTION

The following material was developed to predict total particulate emission factors for gasoline and diesel fueled on-road vehicles, trucks and motorcycles at various vehicle speeds for particles in the respirable size range (less than 10 microns). Particulate emissions from these vehicles may also be determined at other size intervals less than 10 microns (e.g., less than 7.5, 5, or 2.5 microns).

User inputs to the equations to determine these emission factors include area travel fractions by vehicle class, vehicle miles traveled, vehicle speed, particle size limits of interest and calendar year.

This report presents particulate emission factor equations as the sum of individual masses of lead salt, organic and sulfate components for leaded and unleaded gasoline fueled vehicles. Composite (i.e., total particulate mass) equations are presented for diesel fueled vehicles and motorcycles, and tire and brake wear particulate. These equations are subsequently accompanied by tabulated emission factors which may be inserted into the appropriate particulate component equations. Fleet sales fractions and travel fractions by model year are included for each vehicle class. The fractions within each vehicle class that are equipped with different emission control systems also are provided. Cumulative distributions of particle size for leaded and unleaded gasoline and diesel fuel are presented both graphically and tabularly. Also, for the benefit of the user, an example calculation of particulate emissions from light-duty vehicles is provided.

The procedure herein can be used to project automotive particulate emissions by those agencies developing State Implementation Plans for particulate matter or by other interested parties within or outside the EPA concerned with size specific particulate emission factor projections for mobile sources.

This document is an updated version of an April 1984 report prepared by the Environmental Protection Agency, Office of Mobile Sources. It has been revised to include estimates of travel fractions and fleet characteristics from the June 1984 EPA report, User's Guide to MOBILE3 (Mobile Source Emissions Model), EPA 460/3-84-002.<sup>44/</sup> Revised estimates of emission control technology fractions also have been included. The methodology presented in this document is consistent with the procedure outlined in the April 15, 1983 EPA report, Supplementary Guidelines for Lead Implementation Plans -- Updated Projections for Motor Vehicle Lead Emissions<sup>1/</sup> which also was recently updated by Energy and Environmental Analysis, Inc.<sup>45/</sup> That report can be used to project the lead component of total particulate emissions for vehicles using leaded and unleaded gasoline. In addition to the lead component, the methodology outlined in this document can be used to develop estimates of three other components of particulate emission factors. Emission factors for organics, sulfates on the Federal Test Procedure (FTP) cycle, and heavy-duty gasoline trucks came from the Draft Study of Particulate Emissions From Motor Vehicles (for Section 214 of the Clean Air Act), by the Environmental Sciences Research Laboratory, Office of Research and Development, U.S. EPA, July 1983.<sup>8/</sup> Sulfates on the Sulfate Emission Test (SET) cycle and motorcycle emission factors came from the March 1981 EPA report, Compilation of Air Pollutant Emission Factors: Highway Mobile Sources EPA-460-3-81-005.<sup>2/</sup> Light- and heavy-duty diesel particulate emission factors are referenced

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\*/ = Reference at end of text.

from the Draft Diesel Particulate Study, Emission Control Technology Division, Office of Mobile Sources, Office of Air and Radiation, U.S. EPA, October 1983.<sup>4/</sup> Emission factor estimate updating is an ongoing process and, in many cases, these values are based on testing of only a few vehicles.

This document has been revised to reflect changes in the lead content of gasoline. On March 7, 1985, EPA issued regulations which require petroleum refiners to drop the average lead content of leaded gasoline to 0.5 g/gallon by July 31, 1985 and 0.1 g/gallon by January 1, 1986 to: 1) reduce the health hazards associated with lead, and 2) to discourage the practice of misfueling which deteriorates the efficiency of vehicle emission control systems. (See Federal Register, Volume 50, No. 45, March 7, 1985.)

## 2. PROJECTING SIZE SPECIFIC TOTAL PARTICULATE EMISSION FACTORS

This report provides a methodology to project areawide total particulate emissions from mobile sources in a given calendar year. Particulate emissions can consist of lead salts, organics and sulfate emissions. The relative amounts vary for different vehicle types, emission control strategies and vehicle operating modes. Analysis of lead particulate indicates that most of the exhausted lead appears as salts,  $PbClBr$ . Therefore, estimates of the mass of lead particulate will be considerably larger than those predicted by the lead document, which predicts the mass of lead alone. Organic emissions include both soluble organics and elemental carbon and are important contributors to total particulate emissions from all vehicles, especially diesels. Sulfate emissions, mostly from unleaded gasoline-fueled vehicles equipped with catalysts, also are important contributors to total vehicular particulate emissions.

Section 2.1 provides an overview of: 1) the methodology used to calculate total areawide particulate emissions, and 2) the computations required to estimate the individual emission factor components by vehicle category and type of particulate. The detailed emission factor component equations for light-duty vehicles and light-duty trucks are discussed in Section 2.2. Equations for heavy-duty vehicles are described in Section 2.3. Section 2.4 presents the calculations required for motorcycles and Section 2.5 provides brake and tire wear particulate emission factor components.

### 2.1 OVERVIEW OF METHODOLOGY

Areawide particulate emissions (shown in Equation (2-1)) are a function of calendar year, average vehicle speed, vehicle class travel fractions, the particle size range of interest and the vehicle class emissions

associated with the calendar year and vehicle speed. With the exceptions of the vehicle class emission factors, all of the above parameters are inputs selected by the user on an areawide basis to obtain the desired output of mobile source particulate emissions for the area of interest.

$$EF_{pm,n,s} = \sum_{i=1}^6 t_{i,n} EF_{i,n,s} + EF_{brakes} (M_B) + EF_{tires} \quad (2-1)$$

where  $EF_{pm,n,s}$  = size specific all-vehicle class total particulate emission factor on January 1 of calendar year n at vehicle speed s (g/mile)

i = vehicle class designator; 1 = light-duty vehicles (LDV), 2 = light-duty trucks I (LDT1), 3 = light-duty trucks II (LDT2), 4 = heavy-duty gas vehicles (HDGV), 5 = heavy-duty diesel vehicles (HDDV), 6 = motorcycles (MC)

s = vehicle speed; avg. Federal Test Procedure (FTP) = 19.6, avg. Sulfate Emissions Test (SET) = 34.8 (miles/hr); (Note: The FTP and SET are driving cycles used for the determination of emission factors.)

$t_{i,n}$  = area travel fraction of vehicle class i in calendar year n

$EF_{i,n,s}$  = particulate emission factor for vehicle class i in calendar year n at vehicle speed s (g/mile)

$EF_{brakes}$  = airborne brake wear particulate emission factor component = 0.0128 grams/mile; this emission factor component is assumed to be the same for all vehicle classes, vehicle speeds and calendar years (all i, s, and n) due to lack of separate information for each i, s, and n

$EF_{tires}$  = airborne tire wear particulate emission factor component = 0.002 grams/mile; this emission factor component is assumed to be the same for all vehicle classes, vehicle speeds and calendar years (all i, s, and n) due to lack of separate information for each i, s, and n

$M_B$  = fraction of airborne particles less than a user-specified size cutoff ( $0.1-10\mu$ ) that are attributable to vehicle brake wear, from Table 2-20 or Figure 2-4

The vehicle classes for which emission factor estimates may be obtained include: 1) light-duty vehicles (passenger cars), 2) light-duty trucks I (0-6000 lbs. GVWR), 3) light-duty trucks II (6001-8500 lbs. GVWR), 4) heavy-duty gas vehicles (greater than 8,501 lbs. GVWR), 5) heavy-duty diesel vehicles (greater than 8,501 lbs. GVWR), and 6) motorcycles.

The exhaust emission factors for each vehicle class for a given calendar year ( $EF_{i,n,s}$ ) are broken down into component emission factors in Equation (2-2). The components represent the masses of lead salt, organic and sulfate emissions from both leaded and unleaded gasoline fueled vehicles and total particulate mass from diesel vehicles--all of which are multiplied by the fraction of total vehicles of a given model year designed for use on these three fuel types. The sum of these components for each model year is also multiplied by the fraction of the vehicle class travel (disaggregated by gasoline and diesel fuel types for all vehicle categories except light-duty vehicles) that is attributable to that model year in the calendar year of interest. For example, the component ( $EF_{i,j,k,n,L}$ ) represents the emissions in grams per mile of lead salts ( $k=1$ ) from vehicle class  $i$  emitted from model year  $j$  gasoline vehicles that are on the road in calendar year  $n$  and are designed for use on leaded fuel. These emission components must be summed up over the twenty model years prior to the calendar year of interest to include all the contributing fractions of emissions from vehicles on the road.

$$EF_{i,n,s} = \sum_{j=n-19}^n \left[ (EF_{i,j,k_1,n,L} + EF_{i,j,k_2,L} + EF_{i,j,k_3,L})(F_{L,i,j}) \right. \quad (2-2) \\ \left. + (EF_{i,j,k_1,n,NL} + EF_{i,j,k_2,NL} + EF_{i,j,k_3,NL})(F_{NL,i,j}) \right] m_{i,j,G} \\ + (EF_{i,j,D})(F_{D,i,j}) m_{i,j,D}$$

where  $j$  = model year  $j = n-19, n-18, \dots, n-2, n-1, n$

$L$  = vehicles designed for use on leaded fuel

$NL$  = vehicles designed for use on unleaded fuel

$k$  = component of total particulate emission factor  
 $(k_1 = \text{lead}, k_2 = \text{organic}, k_3 = \text{sulfate})$  expressed  
 individually for gasoline vehicles and trucks  
 (except motorcycles) and cumulatively for diesel  
 vehicles and trucks and motorcycles

$F_{L,1,j}$  = fraction of the vehicle class 1 fleet designed for  
 use on leaded gasoline in model year  $j$

$F_{NL,1,j}$  = fraction of the vehicle class 1 fleet designed for  
 use on unleaded gasoline in model year  $j$

$F_{D,1,j}$  = fraction of the vehicle class 1 fleet designed for  
 use on diesel fuel in model year  $j$

$m_{1,j,G}$  = travel fraction for all gasoline vehicles in class  
 1 in model year  $j$

$m_{1,j,D}$  = travel fraction for all diesel vehicles in class 1  
 in model year  $j$

Component emission factors are derived for each vehicle class over different model years at average speeds of 19.6 mph (cyclic driving comparable to average speed of the Federal Test Procedure) and 34.8 mph (cruising conditions comparable to the average speed of the Sulfate Emissions Test). Emission factors for speeds between 19.6 mph and 34.8 mph can be linearly interpolated.

As the reader will note in the following sections, the calculation of these component emission factors is highly dependent on the assumptions made concerning particle size distribution. Distributions of particle size are different for leaded gasoline, unleaded gasoline and diesel fueled vehicles as well as brake and tire wear particles. They are also

different for various conditions of vehicle driving cycle (speed) and load. For the purposes of this report, however, typical or average conditions are presented to facilitate the determination of vehicle particulate emissions versus particle size.

Particle size distributions for leaded, unleaded and diesel fueled vehicles and brake wear particles are contained in Table 2-20 and also in Figures 2-1, 2-2, 2-3, and 2-4 (no distributions are available for tire wear particulate). Typically, the average diameter of particles emitted from vehicles fueled with leaded gasoline are the largest, particles emitted from vehicles fueled with unleaded gasoline are somewhat smaller and particles emitted from diesel fueled vehicles are smaller yet. Some of the data for the size distribution of lead particles are conflicting (e.g., Moran et al, 1971 which shows a larger fraction of the lead in smaller size ranges than the other leaded gasoline references). Thus, these data are less certain than those for unleaded and diesel particles. References for those reports used in the determination of particle size distributions of leaded, unleaded and diesel fueled vehicle emissions and brake wear emissions are listed in Table 2-20.

Values for  $M_L$ ,  $M_{NL,C}$ ,  $M_{NL,NC}$ ,  $M_D$ , and  $M_B$  should be expressed as dimensionless fractions of total particulate by weight emitted below a given size cutoff. Values may be read directly from Table 2-20 for the data points listed therein, or may be read off the graphs of continuous cumulative particle size distributions in Figures 2-1, 2-2, 2-3, and 2-4 for interpolated size cutoffs (e.g.,  $6.5 \mu$ ,  $2.5 \mu$ ).

## 2.2 LIGHT-DUTY VEHICLES AND LIGHT-DUTY TRUCKS I AND II

This section presents the lead, sulfate and organic emission factor equations for gasoline-fueled light-duty vehicles and light-duty trucks I and II. In addition, composite particulate emission factors are

presented for light-duty diesel vehicles and light-duty diesel trucks. The fractions of light-duty vehicles and light-duty trucks by model year which operate on leaded or unleaded gasoline or diesel fuel are presented in Tables 2-4, 2-9, and 2-12. Tables 2-5, 2-10, 2-13, and 2-14 contain information on light-duty vehicle and light-duty truck travel fractions from model years n to n-19. To remain consistent with the data used in MOBILE3, travel fractions are assumed to be identical for gas and diesel light-duty vehicles; but separate travel fractions are used to characterize gasoline versus diesel light-duty trucks I and light-duty trucks II.

### 2.2.1 Lead Emission Factors

Lead emission factors are calculated in the same manner as in the recent report entitled, Supplementary Guidelines for Lead Implementation Plans -- Updated Projections for Motor Vehicle Lead Emissions, hereinafter referred to as the "lead document."<sup>1/</sup> These lead emission estimates are multiplied by a factor of 1.557 to account for the halogens, typically bromine and chlorine, which combine with lead to form total lead salt particulate emissions. This factor was obtained from a report by the Ethyl Corporation entitled Composition, Size, and Control of Automotive Exhaust Particulates, and is the ratio of PbClBr mass to Pb mass based on FTP results of 16 test vehicles.<sup>22/</sup>

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#### LDV (Pre-1971) and LDT (Pre-1971): Leaded Fuel

For  $i=1,2,3$   $j=n-19, \dots, 1970$   $k=1$   $C_s = \text{from Table 2-7}$   $a_{s1,j} = (0.75)$ :

$$EF_{i,j,k1,n,L} = \left[ Pb_{L,n}(0.887)(M_L) + \right. \quad (2-3a)$$

$$\left. Pb_{NL,n}(0.113)(M_{NL,NC}) \right] \frac{(0.75)(1.557)}{(E_{c,i,j})(C_s)}$$

where  $a_s$  = fraction of lead burned that is exhausted; for all non-catalyst vehicles and for catalyst vehicles using unleaded gasoline  $a_{s1,j} = 0.75$  (i.e., 75 percent); for catalyst vehicles using unleaded gasoline in 1975-1980,  $a_{s2,j} = 0.40$ ; for catalyst vehicles using leaded gasoline in 1981 and later,  $a_{s2,j} = 0.44$  (see Table 2-22)

$C_s$  = speed-dependent fuel economy correction factor based on steady cruise or cyclic driving; available from Table 2-7 (nondimensional)

$Pb_{NL,n}$  = lead content of unleaded gasoline in calendar year n from Table 2-2 (g/gal)

$Pb_{L,n}$  = average lead content of leaded gasoline in calendar year n from Table 2-2 (g/gal)

$E_{c,i,j}$  = city/highway combined on-road fuel economy for model year j and vehicle class i from Table 2-6 (miles/gallon)

$M_L$  = fraction of particles less than a user specific size cutoff ( $0.1-10\mu$ ) that are emitted from vehicles that are fueled with leaded gasoline, from Table 2-20 or Figure 2-1

$M_{NL,C}$  = fraction of particles less than a user specified size cutoff ( $0.1-10\mu$ ) that are emitted from catalyst vehicles that are fueled with unleaded gasoline, from Table 2-20 or Figure 2-2

$M_{NL,NC}$  = fraction of particles less than a user specified size cutoff ( $0.1-10\mu$ ) that are emitted from non-catalyst vehicles that are fueled with unleaded gasoline, from Table 2-19 or Figure 2-2

LDV (MY 1971-1974) and LDT (MY 1971-1978): Leaded Fuel

For  $i=1,2$   $j=1971,\dots,1974$   $k=1$   $C_s$ =from Table 2-7  $a_{s1,j}=0.75$ :  
and For  $i=3$   $j=1971,\dots,1978$

$$EF_{i,j,k1n,L} = \left[ Pb_{L,n}(0.916)(M_L) + \right. \quad (2-3b)$$

$$\left. Pb_{NL,n}(0.084)(M_{NL,NC}) \right] \frac{(0.75)(1.557)}{(E_{c,i,m})(C_s)}$$

---

LDV (MY 1975+) and LDT (MY 1979+): Leaded Fuel

For  $i=1,2$   $j=1975,\dots,n$   $k=1$   $C_s$ =from Table 2-7  $a_{s1,j}=0.75$ :  
and For  $i=3$   $j=1979,\dots,n$

$$EF_{i,j,k1n,L} = \left[ Pb_{L,n}(0.724)(M_L) + Pb_{NL,n}(0.276)(M_{NL,NC}) \right] \frac{(a_{s1,j})(1.5557)}{(E_{c,i,j})(C_s)} \quad (2-4)$$


---

LDV (MY 1975+) and LDT (MY 1975+): Unleaded Fuel

For  $i=1,2,3$   $j=1975,\dots,n$   $k=1$   $C_s$ =from Table 2-7  $a_s$ =from Table 2-22:

$$EF_{i,j,k1n,NL} = \left[ (Pb_{NL,n})(1-r_i)(M_{NL,C})(a_{s1,j}) + (Pb_{L,n}(r_i)(M_L)(F_{i,j,NL,NOCAT}) + P_i(F_{i,j,NL,CAT})(a_{s1,j})) + Pb_{L,n}(r_i)(M_L)(1-P_i)(F_{i,j,NL,CAT})(a_{s,2,j}) \right] \frac{1.557}{E_{c,i,j}(C_s)} \quad (2-5)$$

where  $r_i$  = misfueling rate for vehicle class  $i$  from Table 2-19

$P_i$  = fraction of catalyst equipped vehicles with catalysts removed from Table 2-23

The calculation of area lead particulate emissions necessitates the determination of the percentage of burned lead exhausted ( $a_s$ ). A value for  $a_s$  of 0.75 (i.e., 75 percent of the lead burned is exhausted) should be used for non-catalyst equipped, gasoline-powered vehicles. The 0.75 value is based on tests which measured exhaust emissions under cyclic driving conditions and found that 17 percent of the lead is retained by the engine (in the oil and combustion chamber) and 8 percent is retained by the muffler and exhaust pipes.<sup>31/</sup> For gasoline powered vehicles equipped with catalysts, a value of  $a_s=0.40$  for 1975 to 1980 and  $a_s=0.44$

for 1981 and later model year vehicles that have been misfueled, should be used. (For properly fueled catalyst vehicles the values of  $a_s$  for all model years is 0.75.) The value of  $a_s$  was computed from lead retention of monolithic and pelleted catalysts, respectively, and weighted for the sales mix of these catalysts in each time frame. The values of  $a_s$  are not assumed to vary with speed, since  $a_s$  is more correlated with driving mode, e.g., acceleration, cruise or deceleration, rather than speed alone, and little data is available to make  $a_s$  sensitive to all of these variables.

Combined city/highway fuel economy ( $E_{c,i,j}$ ) is yet another factor affecting area lead particulate emissions. Fuel economy versus model year is provided in Table 2-6.

Lead particulate emissions can be determined at any speed by using Equations (2-3), (2-4), and (2-5) (for light-duty vehicles and trucks) and the appropriate value of the speed dependent fuel economy correction factor ( $C_s$ ) for the vehicle speed of interest. Values of  $C_s$  at various speeds are provided in Table 2-7. It should be noted that average vehicle speed and  $C_s$  can be determined for an area by either of two approaches. One approach is to base  $C_s$  on the average vehicle speed for the area of concern. The average area vehicle speed should be a weighted average based on average speeds and VMT data for the various roadway classifications, such as limited access (greater than 5 mph), suburban roads (35 mph) and urban streets (25 mph or less). The other approach, which is considered more accurate, is to determine  $C_s$  and area emissions separately for each roadway classification (and average speed).

Area lead particulate emissions also are dependent upon the lead content of gasoline in a given calendar year. Values for the lead content of leaded ( $Pb_{L,n}$ ) and unleaded gasoline ( $Pb_{NL,n}$ ) are contained in Table 2-2. Values for future years will be updated as new information becomes available.

#### 2.2.1.1 Misfueling and Fuel Switching

EPA has observed that misfueling rates (i.e., percentage of vehicles designed for use on unleaded gasoline that use leaded gasoline) are dependent on vehicle mileage and increase with vehicle mileage accumulation. Strictly speaking, this dependence on mileage should be reflected in the calculation of particulate emissions, with each model year receiving its own misfueling rate. However, this further complicates an already complex calculation. To give the user a choice, this report offers both the option of using a single average misfueling rate for all model years of a given vehicle class and exact misfueling rates for each vehicle class by vehicle age. The single average rates are determined for the weighted average mileage accumulated for each vehicle class and are listed in Table 2-19 for inspection and maintenance (I/M) and non-I/M areas. In other words, in the calculation of emission factors from 1975 on, the misfueling rate ( $r_i$ ) depends only on which vehicle class (i) is being considered and whether the area of interest has an I/M program. As a result, misfueling rates and particulate emissions will be slightly overestimated, with the degree of overestimation declining with later evaluation years and essentially disappearing in 1995. For users who desire more accuracy, Table 2-19a gives exact misfueling rates for different vehicle ages and classes affected by misfueling.

The use of leaded gasoline on vehicles designed for unleaded fuel results in lead salt emissions. Since most of these vehicles have catalysts, the lead results in poisoning of the catalyst so that organic particulate emissions can be assumed to increase to the levels found with non-catalyst vehicles. Also, catalyst poisoning should result in no sulfur dioxide oxidation to sulfates. Sulfate levels are therefore assumed to be the same as those from non-catalyst vehicles.

Discretionary fuel switching (i.e., percentage of vehicles designed for use on leaded gasoline that use unleaded gasoline) is assumed to equal 11.3 percent of the leaded fleet prior to 1971, and 8.4 percent from 1971 to 1974 for the LDV and LDT I categories. The discretionary rate for the LDT II class is 8.4 percent from 1971 to 1978, and 27.6 percent thereafter. For the LDV and LDTI classes, discretionary switching is assumed to be 27.6 percent after 1974. These discretionary rates apply only to the lead salt component of light-duty vehicle and light-duty truck I and II emissions. The misfueling rates employed here were used in the December 1983 EPA report, Anti-Tampering and Anti-Misfueling Programs to Reduce In-Use Emissions from Motor Vehicles, EPA-AA-TSS-83-10.<sup>3/</sup> The discretionary fuel switching rates were obtained from Energy and Environmental Analysis, Inc., Assessment of Current and Projected Trends in Light-Duty Vehicle Fuel Switching, June 1984.<sup>7/</sup>

## 2.2.2 Organic and Sulfate Emission Factors

### 2.2.2.1 Control System Fractions

Organic and sulfate emissions of gasoline-fueled vehicles depend on the type of vehicle emission control system in addition to the vehicle model year. The fraction of vehicles with different emission control systems to which different emission factors are applied are handled similarly to the fleet sales fractions for leaded, unleaded and diesel vehicles versus model year. The main difference is that these are fractions of the total number of vehicles designed for use of unleaded fuel and not the total number of vehicles in each vehicle class. These fractions are listed in Tables 2-3, 2-8, and 2-11 for light-duty vehicles and light-duty trucks I and II, respectively. These vehicle classes have a relatively wide range of control technology and, as a result, have a wide range of emission factor estimates. It should be noted that a small number of non-catalyst equipped vehicles have been certified for use on unleaded gasoline since 1975. These vehicles constitute a very

small percentage of the total non-catalyst fleet, but are nonetheless considered in this report and have been given their own control system fraction category ( $F_{i,j,NL,NOCAT}$ ).

The light-duty vehicle and truck emission control system fractions were obtained from the "sales-weighted" EPA emission factor in-use vehicle test data base. This data base contains gasoline-fueled vehicle mixes approximating the sales mixes for the 1975 through 1982 model years. All vehicles and trucks prior to 1975 models are assumed to be designed for use on leaded fuel (i.e., no diesel or catalyst vehicles). Emission control system fractions for 1983 and later LDVs are determined from recent projections by Energy and Environmental Analysis, Inc. in a report entitled, Forecasts of Emission Control Technology 1983-1990.<sup>38/</sup>

Data for 1975 through 1978 light-duty truck I technology fractions were obtained by combining EPA fuel economy data base sales figures by engine displacement and model type and Federal Certification Test Results for these years from the Federal Register, Volume 40, No. 48, March 11, 1975;<sup>9/</sup> Volume 41, No. 46, March 8, 1976;<sup>10/</sup> Volume 42, No. 110, June 8, 1977;<sup>11/</sup> and Volume 43, No. 181, September 18, 1978.<sup>12/</sup> The certification data provided emission control systems by model type and engine displacement which were matched with fuel economy sales fractions. These two data sources also served as the basis for deriving the 1979-1981 light-duty truck technology fractions.

Data for 1982 through 1984 light-duty trucks I and II technology fractions were obtained by subtracting California sales figures by engine family from Federal sales figures given in the EPA Certification data base for those years. Forecasts of post-1984 light-duty truck I and II technology fractions were developed internally and are consistent with data used for EPA emission factor projections.

#### 2.2.2.2 Organic and Sulfate Emission Factor Components

Organic and sulfate emission factors for light-duty vehicles and light-duty trucks vary by model year, control system, vehicle speed and fuel type (leaded versus unleaded). These emission factors are derived from emission test data and are listed in Table 2-1 in terms of grams per mile. This table of emission factors is used in the following sets of equations to calculate LDV and LDT organic and sulfate emission factor components. (Table 2-1 also refers the user to the proper equation(s) listed below to which each emission factor should be applied.)

##### Organic Emission Factor Components

LDV and LDT (Pre-1970): Leaded Fuel, Avg. Speed = All

For  $i=1,2,3$   $j=n-19, \dots, 1969$   $k=2$ :

$$EF_{i,j,k_2,L} = 0.193 M_L \text{ (g/mile)} \quad (2-6)$$

---

LDV AND LDT (1971-1974): Leaded Fuel, Avg. Speed = All

For  $i=1,2,3$   $j=1970, \dots, 1974$   $k=2$ :

$$EF_{i,j,k_2,L} = 0.068 M_L \text{ (g/mile)} \quad (2-7)$$

---

LDV and LDT (1975+): Leaded Fuel, Avg. Speed = All

$$EF_{i,j,k_2,L} = 0.030 M_L \text{ (g/mile)} \quad (2-8)$$

---

LDV and LDT (1975+): Unleaded Fuel, Avg. Speed = All

$$EF_{i,j,k_2,NL} = (1-r_i)(F_{i,j,CAT})(0.017)(M_{NL,C}) \quad (2-9)$$

$$+ (r_i)(F_{i,j,CAT})(0.068)(M_L) + (F_{i,j,NL,NOCAT})(0.030)(M_{NL,NC})$$

where  $F_{i,j,CAT}$  = fraction of the unleaded vehicle class  $i$   
fleet equipped with a catalyst in model year  $j$

$F_{i,j,NL,NOCAT}$  = fraction of the unleaded vehicle class  $i$  fleet  
without a catalyst in model year  $j$

---

Sulfate Emission Factor Components

LDV and LDT (All Model Years): Leaded Fuel, Avg. Speed = 19.6 mph

For  $i=1,2,3$   $j=n-19,\dots,n$   $k=3$   $s=19.6$ :

$$EF_{i,j,k_3,L} = 0.002 M_L \text{ (g/mile)} \quad (2-10)$$

---

LDV and LDT (All Model Years): Leaded Fuel, Avg. Speed = 34.8 mph

For  $i=1,2,3$   $j=n-19,\dots,n$   $k=3$   $s=34.8$

$$EF_{i,j,k_3,L} = 0.001 M_L \text{ (g/mile)} \quad (2-11)$$

---

LDV and LDT (1975+): Unleaded Fuel, Avg. Speed = 19.6

For  $i=1,2,3$   $j=1975,\dots,n$   $k=3$   $s=19.6$

$$\begin{aligned} E_{Fi,j,k_3,NL} = & (1-r_i) \left[ (F_{i,j,CAT/NOAIR})(0.005)(M_{NL,C}) \right. \\ & + (F_{i,j,CAT/AIR})(0.016)(M_{NL,C}) \\ & + (F_{i,j,NL,NOCAT})(0.002)(M_{NL,NC}) \left. \right] \\ & + (r_i)(0.002)(M_L) \end{aligned} \quad (2-12)$$

where  $F_{i,j,CAT/NOAIR}$  = fraction of the unleaded vehicle class  $i$  fleet equipped with a catalyst but no air pump in model year  $j$ ; this includes oxidation catalyst ( $F_{i,j,OXCAT}$ ) and three way catalyst ( $F_{i,j,3WCAT}$ ) vehicles with no air pump

$F_{i,j,CAT/AIR}$  = fraction of the unleaded vehicle class  $i$  fleet equipped with a catalyst and an air pump in model year  $j$ ; this includes oxidation catalyst ( $F_{i,j,OCAT/AIR}$ ) and three-way plus oxidation catalyst ( $F_{i,j,3WCAT/OCAT}$ ) vehicles with air pumps

LDV and LDT (1975+): Unleaded Fuel Avg. Speed = 34.8 mph

For  $i=1,2,3$   $j=1975,\dots,n$   $k=3$   $s=34.8$   $r_i$  = from Table 2-19:

$$\begin{aligned} E_{Fi,j,k_3NL} = & (1-r_i) \left[ (F_{i,j,NL,NOCAT})(0.001)(M_{NL,NC}) \right. \\ & + (F_{i,j,OXCAT})(0.005)(M_{NL,C}) + (F_{i,j,3WCAT})(0.001)(M_{NL,C}) \\ & + (F_{i,j,OXCAT/AIR})(0.020)(M_{NL,C}) + (F_{i,j,3WCAT/OCAT}) \\ & \left. (0.025)(M_{NL,C}) \right] + (r_i)(0.001)(M_L) \end{aligned} \quad (2-13)$$

where  $F_{i,j,OXCAT}$  = fraction of the unleaded vehicle class  $i$  equipped with an oxidation catalyst but no air pump in model year  $j$

$F_{i,j,3WCAT}$  = fraction of the unleaded vehicle class  $i$  equipped with a three-way catalyst in model year  $j$ ; note these vehicles are sometimes equipped with air pumps that are usually only used during vehicle start-up; therefore, the vehicle category as a whole is assumed to emit sulfates at the same rate as non-air pump-equipped vehicles for emission factor consideration

$F_{i,j,OXCAT/AIR}$  = fraction of the unleaded vehicle class  $i$  equipped with an oxidation catalyst and an air pump in model year  $j$

### 2.2.3 Diesel Emission Factors (Light-Duty)

Diesel particulate emission factors for different model years are listed separately for light-duty vehicles and light-duty trucks in Table 2-1. These emission factors are derived from test data and are used in the equations below to calculate total diesel particulate emission factor components for LDVs and LDTs. (Table 2-1 also refers the user to the proper equation below to which each emission factor should be applied.)

#### LDV (Pre-1981): Diesel Fuel

For  $i=1$   $j=n-19, \dots, 1980$ :

$$EF_{i,j,D} = 0.700 M_D \text{ (g/mile)} \quad (2-14)$$

where  $M_D$  = fraction of particles less than a user-specified size cutoff ( $0.1-10 \mu$ ) that are emitted from vehicles that are fueled with diesel fuel, from Table 2-20 or Figure 2-3

---

#### LDV (1981-1986): Diesel Fuel

For  $i=1$   $j=1981, \dots, 1986$ :

$$EF_{i,j,D} = 0.300 M_D \text{ (g/mile)} \quad (2-15)$$

LDV (1987+): Diesel Fuel

For  $i=1$   $j=1987, \dots, n$ :

$$EF_{i,j,D} = 0.200 M_D \text{ (g/mile)} \quad (2-16)$$

---

LDT (Pre-1981): Diesel Fuel

For  $i=1,2,3$   $j=n-19, \dots, 1980$ :

$$EF_{i,j,D} = 0.800 M_D \text{ (g/mile)} \quad (2-17)$$

---

LDT (1981-1986): Diesel Fuel

For  $i=1,2,3$   $j=1981, \dots, 1986$ :

$$EF_{i,j,D} = 0.300 M_D \text{ (g/mile)} \quad (2-18)$$

---

LDT (1987+): Diesel Fuel

For  $i=2,3$   $j=1987, \dots, n$ :

$$EF_{i,j,D} = 0.260 M_D \text{ (g/mile)} \quad (2-19)$$

### 2.3 HEAVY-DUTY VEHICLES

This section presents the lead, sulfate and organic emission factor component equations for gasoline-fueled heavy-duty vehicles. Composite particulate emission factor components for heavy-duty diesel vehicles also are provided. These emission factor components are then used in conjunction with estimates of sales fractions of heavy-duty vehicles by model year and fuel type (Table 2-15) and travel fractions by vintage (Tables 2-16 and 2-17) to calculate total emission factors. As shown in Table 2-15, heavy-duty gasoline vehicles use leaded gasoline prior to 1987. The fraction of unleaded vehicles from 1987 on represents the

8,501-14,000 lbs percentage of heavy-duty gasoline vehicles, and is based on the assumption that the more stringent emission standards currently proposed for 1987 and later heavy-duty gasoline vehicles in the 8,501 to 14,000 lbs range will require the use of oxidation catalysts and air injection. Heavy-duty gasoline vehicles above 14,000 lbs are assumed to consist entirely of leaded gasoline vehicles for all model years. The reader also should note that the travel fractions for heavy-duty diesel trucks in Table 2-17 are specific to calendar year 1987 and are therefore presented for example only. These fractions shift from one calendar year to the next due to the increasing penetration of diesels in the lower mileage, lighter weight categories of heavy-duty trucks (which consists of all vehicles over 8,500 lbs. GVW). To calculate heavy-duty diesel travel fractions in a particular year of interest other than 1987, the reader needs to use the projections of diesel heavy-duty vehicles in-use by GVW category and the estimates of diesel heavy-duty vehicle mileage accumulation by GVW category which are contained in Appendix A.

Table 2-6 presents data on heavy-duty truck fuel economy. Estimates of misfueling for heavy-duty gas vehicles under 14,000 lbs GVW (after model year 1986) are contained in Tables 2-19 and 2-19a. The effect of discretionary fuel switching has not been incorporated in the heavy-duty vehicle emission factor equations due to the lack of data on the current fuel purchase behavior of owners of heavy-duty vehicles. However, as new data become available these equations will be revised accordingly.

#### 2.3.1 Lead Emission Factor Components

The following equations are used to derive lead emission factor components for heavy-duty gas vehicles operated on leaded and unleaded gasoline:

HDGV (Pre-1987): Leaded Fuel

For  $i=4$   $j=n-19, \dots, 1986$   $k=1$   $a_s$  = from Table 2-22:

$$EF_{i,j,k_1,n,L} = \frac{(a_{s1,j})(Pb_{L,n})(1.557)}{E_{c,4,j}} (M_L) \quad (2-20)$$

---

HDGV (1987+): Unleaded Fuel

For  $i=4$   $j=1987, \dots, n$   $k=1$   $a_s$  = from Table 2-2  $r_4$  = from Table 2-19:

$$EF_{i,j,k_1,n,NL} = \frac{(1-r_4)(a_{s1,j})(Pb_{NL,n})(1.557)}{(E_{c,4a,j})^*} (M_{NL,C}) \quad (2-21)$$
$$+ \frac{(r_4)(a_{s2,j})(Pb_{L,n})(1.557)}{E_{c,4a,j}} (M_L)$$

---

HDGV (1987+): Leaded Fuel

For  $i=4$   $j=1987, \dots, n$   $k=1$   $a_s$  = from Table 2-22:

$$EF_{i,j,k_1,n,L} = \frac{(a_{s1,j})(Pb_{L,n})(1.557)}{(E_{c,4b,j})^{**}} (M_L) \quad (2-22)$$

\*4a represents the fuel economy for HDGV1 after 1986.

\*\*4b represents the fuel economy for HDGV2 after 1986.

2.3.2 Organic Emission Factor Components

Organic emission factors for heavy-duty gasoline vehicles are listed in Table 2-1 in g/mile. These factors are used in the equations below to calculate the total HDG organic emission factor component. The reader should note that the HDG organic emission factors listed in Table 2-1 were derived assuming a constant 5.0 mpg for HDG vehicles of all model years. Therefore, the equations below have been adjusted by the factor  $(5.0/E_{c,4,j})$  to account for the HDG fuel economy values currently used in MOBILE3.

HDGV (Pre-1987): Leaded Fuel

For  $i=4$   $j=n-19, \dots, 1986$   $k=2$ :

$$EF_{i,j,k_2,L} = 0.370 (M_L) \left( \frac{5.0}{E_{c,4,j}} \right) \quad (2-23)$$

---

HDGV (1987+): Unleaded Fuel

For  $i=4$   $j=1987, \dots, n$   $k=2$   $r_4 =$  from Table 2-19:

$$EF_{i,j,k_2,NL} = \left[ (1-r_4)(0.054)(M_{NL,C}) + (r_4)(0.163)(M_L) \right] \left( \frac{5.0}{E_{c,4a,j}} \right) \quad (2-24)$$

---

HDGV (1987+): Leaded Fuel

For  $i=4$   $j=1987, \dots, n$   $k=2$ :

$$EF_{i,j,k_2,L} = 0.370 (M_L) \left( \frac{5.0}{E_{c,4b,j}} \right) \quad (2-25)$$

2.3.3 Sulfate Emission Factor Components

Sulfate emission factors for HDG vehicles also are listed in Table 2-1 and are used in the following equations to produce HDG sulfate emission factor components. As with the HDG organic emission factor components, the equations below contain the adjustment factor  $(5.0/E_{c,4,j})$  to reflect the HDG fuel economy values currently used in MOBILE3.

HDGV (Pre-1987): Leaded Fuel

For  $i=4$   $j=n-19, \dots, 1986$   $k=3$ :

$$EF_{i,j,k_3,L} = 0.006 (M_L) \left( \frac{5.0}{E_{c,4,j}} \right) \quad (2-26)$$

---

HDGV (1987+): Unleaded Fuel

For  $i=4$   $j=1987, \dots, n$   $k=3$   $r_4 =$  from Table 2-19:

$$EF_{i,j,k_3,L} = \left[ (1-r_4)(0.048)(M_{NL,C}) + (r_4)(0.006)(M_L) \right] \left( \frac{5.0}{E_{c,4a,j}} \right) \quad (2-27)$$

HDGV (1987+): Leaded Fuel

For  $i=4$   $j=1987, \dots, n$   $k=3$ :

$$EF_{i,j,k3,L} = 0.006 (M_L) \left( \frac{5.0}{E_{c,4b,j}} \right) \quad (2-28)$$

2.3.4 Diesel Particulate Emission Factors

Diesel particulate emission factors (measured in g/mile) for heavy-duty diesel vehicles are derived with the following equations:

HDDV (All Model Years): Diesel Fuel

For  $i=5$   $j=n-19, \dots, n$ :

$$EF_{5,j,D} = 0.7 M_D (CF_{D,j}) \quad (2-29)$$

where  $CF_{D,j}$  = factor for converting gm/bhp-hr to gm/mi,  
from Table 2-21

2.4 MOTORCYCLE EMISSION FACTORS

This section presents the emission factors for motorcycles. Table 2-18 contains travel fractions for the motor vehicle fleet. Motorcycle sales are assumed to consist entirely of leaded gasoline vehicles for all model years. Therefore, misfueling rates for motorcycles are zero.

Discretionary fuel switching rates are not incorporated into the equations due to the lack of data on the fuel purchasing habits of motorcycle owners.

Motorcycle fractions are based on 2-stroke versus 4-stroke emission factor estimates (see Table 2-1). Before 1978, most on-road motorcycle travel was done by 2-stroke vehicles (53.4 percent) and slightly less (46.6 percent) by 4-stroke vehicles according to sales figures in the 1983 Motorcycle Statistical Annual published by the Motorcycle Industry

Council, Inc.<sup>13/</sup> In 1978, more stringent control of motorcycle emissions caused nearly all motorcycle manufacturers to build 4-stroke vehicles for on-road usage. Therefore, it is assumed that all motorcycles from 1978 on are 4-stroke vehicles since nearly all 2-stroke mileage is accumulated off-road.

The equations below present the lead emission factor component calculations for motorcycles. Due to the absence of catalyst emission controls on motorcycles, organic and sulfate emission factor components are not calculated.

MC (Pre-1978): Leaded Fuel

For  $i=6$   $j=n-19, \dots, 1977$ :

$$EF_{6,j,L} = \left[ (0.466)(0.046) + (0.534)(0.330) \right] (M_L) \quad (2-30)$$

$$= 0.198 M_L \text{ (g/mile)}$$


---

MC (1978+): Leaded Fuel

For  $i=6$   $j=1978, \dots, n$ :

$$EF_{6,j,L} = 0.046 M_L \text{ (g/mile)} \quad (2-31)$$

## 2.5 BRAKE AND TIRE WEAR PARTICULATE EMISSION FACTOR COMPONENTS

Additional sources of motor vehicle particulate emissions include brake and tire wear emission components. Limited testing has been performed to estimate the contributions of brake and tire wear emissions to the total light-duty vehicle particulate emission rate. No data exist on the rate at which light-duty trucks, heavy-duty vehicles, or motorcycles emit brake and tire wear emissions. The user should be aware that brake and tire wear particulates are emitted from these vehicle classes at different rates than the light-duty vehicle rate, but since no data exists, the light-duty vehicle rate is used to estimate their contribution to total particulate emission rates.

Brake wear emissions from light-duty vehicles have been measured in a recent study and have been found to consist of significant quantities of particulate in the airborne particle size range. Airborne particulate emission rates for brake wear particles as measured on braking cycles representative of urban driving averaged 0.0128 grams per mile for light-duty gasoline vehicles.<sup>40/</sup> Particle size distribution for brake wear particulate ( $M_B$ ) is included in this reference and is summarized in Table 2-20. The rate of 0.0128 g/mile times the appropriate fraction of  $M_B$  for the particle size cutoff of interest should be added to any calculation of particulate emissions less than 10 microns for all classes of vehicles. In the example calculation in Section 3-0 of this report, for example,  $M_B = 0.98$ , the brake wear particulate emission rate is therefore 0.0125 g/mile and the total light-duty vehicle particulate emission rate is 0.0726 g/mile. In this particular example, therefore, brake wear emissions account for 17 percent of the total particulate emission rate.

Tire wear particulate is generally larger in size than brake wear particulate and therefore consists of fewer particles in the airborne size range. Emission rates for airborne tire wear particulate for light-duty vehicles has been estimated at 0.002 g/mile.<sup>41/ 42/</sup> This rate should be added to calculations of particulate emissions less than 10 microns for all classes of vehicles. The addition of 0.002 g/mile in the example calculation in Section 3-0 indicates that airborne tire wear particulate accounts for about 3 percent of the total light-duty particulate emission rate.

No data on airborne particle size distribution are available for analyses of tire wear particulate emission rates at smaller particle size cutoffs (i.e., 2.5 microns or 7 microns). The user should either interpolate between zero and 10 microns to determine the appropriate emission rate for the distribution of tire wear particles below the desired size cutoff (e.g., at 7 microns tire wear emissions = 0.0014 g/mile and at 2.5 microns tire wear emissions = 0.0005 g/mile) or simply neglect tire wear particulate since it is likely to be negligible in these smaller particle size ranges.

Another source of particulate emissions for which emission factors could be developed is reentrained particulate from particles that have been deposited on road surfaces or possibly road material itself. While information is available on these reentrained particulates,<sup>46/ 47/</sup> they are not considered to be directly emitted by mobile sources and therefore are not included in this report.

TABLE 2-1  
EMISSION FACTORS OF MOTOR VEHICLE ENGINE TOTAL PARTICULATE EMISSIONS

| Applicable Model Year(s)                        | Particulate Component | Control System | Type of Fuel Used | Vehicle Speed (MPH) | Emission Factor (grams/mile) | Equation Used In | Emission Factor Source Reference Number |
|-------------------------------------------------|-----------------------|----------------|-------------------|---------------------|------------------------------|------------------|-----------------------------------------|
| <b>Light-Duty Gasoline Vehicles and Trucks:</b> |                       |                |                   |                     |                              |                  |                                         |
| Pre-1970                                        | Organic               | NOCAT          | Leaded            | All                 | 0.193                        | (2-6)            | 8                                       |
| 1970-1974                                       | Organic               | NOCAT          | Leaded            | All                 | 0.068                        | (2-7)            | 8                                       |
| 1975+                                           | Organic               | NOCAT          | Leaded            | All                 | 0.030                        | (2-8)            | 8(a)                                    |
| 1975+                                           | Organic               | CAT            | Unleaded          | All                 | 0.017                        | (2-9)            | 8(b)                                    |
| 1975+                                           | Organic               | CAT            | Leaded            | All                 | 0.068                        | (2-9)            | 8(c)                                    |
| 1975+                                           | Organic               | NOCAT          | Unleaded          | All                 | 0.030                        | (2-9)            | 8(a)(h)                                 |
| All                                             | Sulfate               | NOCAT          | Leaded            | 19.6                | 0.002                        | (2-10)(2-12)     | 8                                       |
| 1975+                                           | Sulfate               | CAT            | Leaded            | 19.6                | 0.002                        | (2-12)           | 8(d)                                    |
| Pre-1975                                        | Sulfate               | NOCAT          | Leaded            | 34.8                | 0.001                        | (2-11)           | 2                                       |
| 1975+                                           | Sulfate               | CAT/NOAIR(f)   | Unleaded          | 19.6                | 0.005                        | (2-12)           | 8                                       |
| 1975+                                           | Sulfate               | CAT/AIR(g)     | Unleaded          | 19.6                | 0.016                        | (2-12)           | 8                                       |
| 1975+                                           | Sulfate               | NOCAT          | Unleaded          | 19.6                | 0.002                        | (2-12)           | 8(e)                                    |
| 1975+                                           | Sulfate               | NOCAT          | Leaded            | 34.8                | 0.001                        | (2-11)           | 2                                       |
| 1975+                                           | Sulfate               | NOCAT          | Unleaded          | 34.8                | 0.001                        | (2-13)           | 2                                       |
| 1975+                                           | Sulfate               | OXCAT/NOAIR    | Unleaded          | 34.8                | 0.005                        | (2-13)           | 2                                       |
| 1975+                                           | Sulfate               | 3WCAT          | Unleaded          | 34.8                | 0.001                        | (2-13)           | 2                                       |
| 1975+                                           | Sulfate               | OXCAT/AIR      | Unleaded          | 34.8                | 0.020                        | (2-13)           | 2                                       |
| 1975+                                           | Sulfate               | 3WCAT/AIR      | Unleaded          | 34.8                | 0.025                        | (2-13)           | 2                                       |
| 1975+                                           | Sulfate               | CAT            | Leaded            | 34.8                | 0.001                        | (2-13)           | 2(d)                                    |
| <b>Light-Duty Diesel Vehicles and Trucks:</b>   |                       |                |                   |                     |                              |                  |                                         |
| Pre-1981                                        | All LDDV              | -              | Diesel            | All                 | 0.700                        | (2-14)           | 4                                       |
| 1981-1986                                       | All LDDV              | -              | Diesel            | All                 | 0.300                        | (2-15)           | 4                                       |
| 1987+                                           | All LDDV              | -              | Diesel            | All                 | 0.200                        | (2-16)           | 4                                       |
| Pre-1981                                        | All LDDV              | -              | Diesel            | All                 | 0.800                        | (2-17)           | 4                                       |
| 1981-1986                                       | All LDDV              | -              | Diesel            | All                 | 0.300                        | (2-18)           | 4                                       |
| 1987+                                           | All LDDV              | -              | Diesel            | All                 | 0.260                        | (2-19)           | 4                                       |

TABLE 2-1 (cont'd)

## EMISSION FACTORS OF MOTOR VEHICLE ENGINE TOTAL PARTICULATE EMISSIONS

| Applicable<br>Model Year(s)        | Particulate<br>Component | Control<br>System | Type of<br>Fuel Used | Vehicle<br>Speed<br>(MPH) | Emission<br>Factor<br>(grams/mile) | Equation<br>Used In | Emission<br>Factor Source<br>Reference Number |
|------------------------------------|--------------------------|-------------------|----------------------|---------------------------|------------------------------------|---------------------|-----------------------------------------------|
| <u>Heavy-Duty Gasoline Trucks:</u> |                          |                   |                      |                           |                                    |                     |                                               |
| Pre-1987                           | Organic                  | NOCAT             | Leaded               | All                       | 0.370                              | (2-23)              | 8                                             |
| 1987+                              | Organic                  | CAT/AIR           | Unleaded             | All                       | 0.054                              | (2-24)              | 8                                             |
| 1987+                              | Organic                  | CAT/AIR           | Leaded               | All                       | 0.163                              | (2-24)              | (i)                                           |
| 1987+                              | Organic                  | NOCAT             | Leaded               | All                       | 0.370                              | (2-25)              |                                               |
| Pre-1987                           | Sulfate                  | NOCAT             | Leaded               | All                       | 0.006                              | (2-26)              | 8                                             |
| 1987+                              | Sulfate                  | CAT/AIR           | Unleaded             | All                       | 0.048                              | (2-27)              | 8                                             |
| 1987+                              | Sulfate                  | NOCAT             | Leaded               | All                       | 0.006                              | (2-27)              | 8                                             |
| <u>Heavy-Duty Diesel Trucks:</u>   |                          |                   |                      |                           |                                    |                     |                                               |
| All                                | All HDDT@                | -                 | Diesel               | All                       | 0.700*                             | (2-29)              | 8                                             |
| <u>Motorcycles:</u>                |                          |                   |                      |                           |                                    |                     |                                               |
| All                                | 4-Stroke                 | -                 | Leaded               | All                       | 0.046                              | (2-30)(2-31)        | 2                                             |
| All                                | 2-Stroke                 | -                 | Leaded               | All                       | 0.330                              | (2-30)              | 2                                             |

(a) Ratio 1.5/3.4 of 1970-74 organic value.

(b) Combined value of organic from catalyst/no air and catalyst/air vehicles.

(c) Same as 1970-74 no catalyst leaded organic value.

(d) Misfueled vehicles.

(e) Same as no catalyst leaded value.

(f) Includes oxidation catalyst vehicles and three-way catalyst vehicles without air pumps.

(g) Includes oxidation catalyst vehicles and three-way plus oxidation catalyst vehicles with air pumps.

(h) Value should actually be higher for the light-duty truck II class (much like the 1970-74 organic value) but no data exist.

(i) Letter from Phil Lorang, July 12, 1984.

\*g/Bhp-hr

TABLE 2-2  
LEAD CONTENT OF GASOLINE

| <u>Year</u> | <u>Leaded Gasoline*</u><br><u>(g/gal)</u> | <u>Unleaded Gasoline</u><br><u>(g/gal)</u> |
|-------------|-------------------------------------------|--------------------------------------------|
| 1974        | 1.79                                      | 0.014                                      |
| 1975        | 1.82                                      | 0.014                                      |
| 1976        | 2.02                                      | 0.014                                      |
| 1977        | 2.03                                      | 0.014                                      |
| 1978        | 1.94                                      | 0.014                                      |
| 1979        | 1.85                                      | 0.014                                      |
| 1980        | 1.38                                      | 0.014                                      |
| 1981        | 1.15                                      | 0.014                                      |
| 1982        | 1.24                                      | 0.014                                      |
| 1983        | 1.14                                      | 0.014                                      |
| 1984        | 1.10                                      | 0.014                                      |
| 1985        | 0.50                                      | 0.014                                      |
| 1986        | 0.10                                      | 0.014                                      |
| 1987        | 0.10                                      | 0.014                                      |
| 1988        | 0.10                                      | 0.014                                      |
| 1989        | 0.10                                      | 0.014                                      |
| 1990        | 0.10                                      | 0.014                                      |

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\*1974-1982: Lead content based upon data submitted to EPA on historical sales data for leaded gasoline and data indicating the actual pooled average lead content. The value for unleaded gasoline is based on recent MVMA fuel surveys.

1983-1990: Lead content based upon requirements for average lead content of leaded gasoline. During the first half of 1983, small refineries were subject to a pooled average lead standard. Recent EPA regulations require refiners to reduce the lead content of leaded gasoline to 0.5 g/gal by July 31, 1985 and to 0.1 g/gal by January 1, 1986 and thereafter. (See Federal Register, Vol. 50, No. 45, March 7, 1985.)

TABLE 2-3  
FRACTION OF LIGHT-DUTY VEHICLE MODEL YEAR SALES EQUIPPED WITH  
DIFFERENT EMISSION CONTROL SYSTEMS  
(Low-Altitude Non-California)

| System                       | Pre-<br>1975 | 1975 | 1976 | 1977  | 1978  | 1979  | 1980  | 1981  | 1982  | 1983  | 1984  | 1985  | 1986  | 1987  | 1988+ |
|------------------------------|--------------|------|------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| F <sub>L,1,j</sub>           | 1.000        | .128 | .134 | .158  | .126  | .097  | 0     | 0     | 0     | 0     | 0     | 0     | 0     | 0     | 0     |
| F <sub>1,j,NL,NOCAT</sub>    | 0            | .081 | .020 | 0     | 0     | 0     | 0     | 0     | 0     | 0     | 0     | 0     | 0     | 0     | 0     |
| F <sub>1,j,OXCAT/NOAIR</sub> | 0            | .597 | .637 | .650  | .650  | .640  | .421  | .033  | 0     | 0     | 0     | 0     | 0     | 0     | 0     |
| F <sub>1,j,OXCAT/AIR</sub>   | 0            | .322 | .343 | .350  | .350  | .345  | .514  | .099  | .142  | .109  | 0     | 0     | 0     | 0     | 0     |
| F <sub>1,j,3WCAT</sub>       | 0            | 0    | 0    | 0     | 0     | .015  | .053  | .263  | .313  | .244  | .396  | .532  | .587  | .641  | .704  |
| F <sub>1,j,3WCAT/OXCAT</sub> | 0            | 0    | 0    | 0     | 0     | 0     | .012  | .605  | .545  | .647  | .604  | .468  | .414  | .359  | .296  |
| F <sub>D,1,j</sub>           | 0            | .003 | .003 | .004  | .009  | .028  | .034  | .061  | .046  | .053  | .060  | .066  | .073  | .080  | .090  |
| F <sub>1,j,CAT</sub>         | 0            | .919 | .980 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 |
| F <sub>1,j,CAT/NOAIR</sub>   | 0            | .597 | .637 | .650  | .650  | .655  | .474  | .296  | .149  | .194  | .237  | .381  | .450  | .518  | .554  |
| F <sub>1,CAT/AIR</sub>       | 0            | .322 | .343 | .350  | .350  | .345  | .526  | .704  | .851  | .806  | .763  | .691  | .587  | .482  | .446  |

SOURCES: U.S. EPA Emission Factor In-Use Test Vehicle Data Base.  
EEA Forecasts of Emission Control Technology 1982-1990 (used for years 1982-1988+).  
U.S. EPA Fuel Economy Data Base.

NOTES: Model year columns do not add up to 1.000. Only F<sub>L,1,j</sub> and F<sub>D,1,j</sub> are fractions of all LDVs. All other systems are fractions of all unleaded LDVs.

TABLE 2-4  
FLEET SALES FRACTIONS  
Light-Duty Vehicles

| Model<br>Years | Nonleaded Gasoline<br>Fraction of LDV<br>Fleet, $F_{NL,l,j}^*$ | Leaded Gasoline<br>Fraction of LDV<br>Fleet, $F_{L,l,j}$ | Diesel Fraction<br>of LDV Fleet,<br>$F_{D,l,j}^{**}$ |
|----------------|----------------------------------------------------------------|----------------------------------------------------------|------------------------------------------------------|
| Pre-1975       | 0.000                                                          | 1.000                                                    | 0.000                                                |
| 1975           | 0.869                                                          | 0.128                                                    | 0.003                                                |
| 1976           | 0.863                                                          | 0.134                                                    | 0.003                                                |
| 1977           | 0.838                                                          | 0.158                                                    | 0.004                                                |
| 1978           | 0.865                                                          | 0.126                                                    | 0.009                                                |
| 1979           | 0.875                                                          | 0.097                                                    | 0.028                                                |
| 1980           | 0.966                                                          | 0.000                                                    | 0.034                                                |
| 1981           | 0.939                                                          | 0.000                                                    | 0.061                                                |
| 1982           | 0.954                                                          | 0.000                                                    | 0.046                                                |
| 1983           | 0.947                                                          | 0.000                                                    | 0.053                                                |
| 1984           | 0.940                                                          | 0.000                                                    | 0.060                                                |
| 1985           | 0.934                                                          | 0.000                                                    | 0.066                                                |
| 1986           | 0.927                                                          | 0.000                                                    | 0.073                                                |
| 1987           | 0.920                                                          | 0.000                                                    | 0.080                                                |
| 1988           | 0.910                                                          | 0.000                                                    | 0.090                                                |
| 1989           | 0.900                                                          | 0.000                                                    | 0.100                                                |
| 1990           | 0.887                                                          | 0.000                                                    | 0.113                                                |
| 1991           | 0.887                                                          | 0.000                                                    | 0.113                                                |
| 1992           | 0.886                                                          | 0.000                                                    | 0.114                                                |
| 1993           | 0.886                                                          | 0.000                                                    | 0.114                                                |
| 1994           | 0.885                                                          | 0.000                                                    | 0.115                                                |
| 1995+          | 0.885                                                          | 0.000                                                    | 0.115                                                |

Where  $F_{NL,l}$  = Estimated fraction of the LDV model year fleet which use nonleaded gasoline

$F_{L,l}$  = Estimated fraction of the LDV model year fleet which use leaded gasoline

$F_{D,l}$  = Estimated fraction of the LDV model year fleet which use diesel fuel

\*Percentages of gasoline vehicles requiring leaded and nonleaded fuel obtained from Energy and Environmental Analysis, Inc., "The Highway Fuel Consumption Model: Tenth Quarterly Report," November 1983.

\*\*Diesel and gasoline sales projections were made by EPA based on data obtained from Energy and Environmental Analysis, Inc., "The Highway Fuel Consumption Model: Tenth Quarterly Report," November 1983.

TABLE 2-5  
TRAVEL WEIGHTING FACTOR CALCULATION\*  
Light-Duty Vehicles

| Vehicle<br>Age | (a)<br>January 1<br>Fraction<br>Total<br>Registration | (b)<br>Annual<br>Mileage<br>Accumulation<br>Rate | (a)(b)  | [(a)(b)/(SUM)]<br>Fraction of LDV<br>Travel by Model Year<br>$m_{l,j,G}$ and $m_{l,j,D^{**}}$ |
|----------------|-------------------------------------------------------|--------------------------------------------------|---------|-----------------------------------------------------------------------------------------------|
| 1              | 0.028                                                 | 12,818                                           | 358.9   | 0.038                                                                                         |
| 2              | 0.107                                                 | 12,639                                           | 1,352.4 | 0.142                                                                                         |
| 3              | 0.100                                                 | 11,933                                           | 1,193.3 | 0.125                                                                                         |
| 4              | 0.094                                                 | 11,268                                           | 1,059.2 | 0.111                                                                                         |
| 5              | 0.088                                                 | 10,639                                           | 936.2   | 0.098                                                                                         |
| 6              | 0.080                                                 | 10,045                                           | 803.6   | 0.084                                                                                         |
| 7              | 0.075                                                 | 9,485                                            | 711.4   | 0.075                                                                                         |
| 8              | 0.069                                                 | 8,955                                            | 617.9   | 0.065                                                                                         |
| 9              | 0.062                                                 | 8,455                                            | 524.2   | 0.055                                                                                         |
| 10             | 0.056                                                 | 7,983                                            | 447.0   | 0.047                                                                                         |
| 11             | 0.050                                                 | 7,538                                            | 376.9   | 0.040                                                                                         |
| 12             | 0.043                                                 | 7,117                                            | 306.0   | 0.032                                                                                         |
| 13             | 0.037                                                 | 6,720                                            | 248.6   | 0.026                                                                                         |
| 14             | 0.031                                                 | 6,345                                            | 196.7   | 0.021                                                                                         |
| 15             | 0.024                                                 | 5,991                                            | 143.8   | 0.015                                                                                         |
| 16             | 0.018                                                 | 5,657                                            | 101.8   | 0.011                                                                                         |
| 17             | 0.012                                                 | 5,341                                            | 64.1    | 0.007                                                                                         |
| 18             | 0.008                                                 | 4,043                                            | 32.3    | 0.003                                                                                         |
| 19             | 0.006                                                 | 4,762                                            | 28.6    | 0.003                                                                                         |
| 20+            | 0.008                                                 | 4,496                                            | 36.0    | 0.004                                                                                         |
| SUM:           |                                                       |                                                  | 9,538.9 |                                                                                               |

\*Data derived from MOBILE3.

\*\*Travel fractions are the same for diesel and gasoline fueled LDVs.

TABLE 2-6  
CITY/HIGHWAY COMBINED ON-ROAD FUEL ECONOMY  
(miles/gallon)

| Model<br>Year | Fuel Economy, $E_{c,i,j}$ |        |      |        |       |        |
|---------------|---------------------------|--------|------|--------|-------|--------|
|               | LDV*                      | LDT1** | LDT2 | HDGV1+ | HDGV2 | HDGV++ |
| Pre-1970      | 13.9                      | 10.6   | 7.9  | -      | -     | 6.5    |
| 1970          | 13.9                      | 10.6   | 7.9  | -      | -     | 6.4    |
| 1971          | 13.2                      | 10.4   | 7.7  | -      | -     | 6.4    |
| 1972          | 13.1                      | 10.2   | 7.4  | -      | -     | 6.4    |
| 1973          | 12.9                      | 9.9    | 7.0  | -      | -     | 6.5    |
| 1974          | 12.6                      | 9.6    | 6.9  | -      | -     | 6.7    |
| 1975          | 13.5                      | 11.6   | 8.8  | -      | -     | 6.8    |
| 1976          | 14.8                      | 12.3   | 9.7  | -      | -     | 7.3    |
| 1977          | 15.5                      | 13.0   | 9.4  | -      | -     | 7.7    |
| 1978          | 16.8                      | 13.4   | 9.6  | -      | -     | 8.0    |
| 1979          | 17.2                      | 14.2   | 9.8  | -      | -     | 8.2    |
| 1980          | 20.0                      | 16.1   | 11.5 | -      | -     | 8.4    |
| 1981          | 21.4                      | 17.7   | 13.3 | -      | -     | 8.6    |
| 1982          | 22.2                      | 18.6   | 13.6 | -      | -     | 8.8    |
| 1983          | 22.2                      | 19.2   | 13.7 | -      | -     | 8.9    |
| 1984          | 22.8                      | 19.9   | 13.9 | -      | -     | 8.9    |
| 1985          | 23.2                      | 20.7   | 14.0 | -      | -     | 9.0    |
| 1986          | 23.8                      | 21.4   | 14.3 | -      | -     | 9.0    |
| 1987          | 24.3                      | 23.0   | 14.5 | 9.5    | 5.6   | 9.0    |
| 1988          | 24.8                      | 23.3   | 14.7 | 9.5    | 5.6   | 9.1    |
| 1989          | 25.2                      | 23.1   | 14.9 | 9.6    | 5.6   | 9.2    |
| 1990          | 25.7                      | 24.0   | 15.2 | 9.7    | 5.6   | 9.2    |
| 1991          | 26.2                      | 24.5   | 15.4 | 9.7    | 5.7   | 9.3    |
| 1992          | 26.6                      | 24.4   | 15.7 | 9.8    | 5.7   | 9.4    |
| 1993          | 27.2                      | 25.3   | 15.9 | 9.8    | 5.7   | 9.4    |
| 1994          | 27.6                      | 25.8   | 16.2 | 9.9    | 5.7   | 9.5    |
| 1995+         | 29.0                      | 26.2   | 16.4 | 10.1   | 5.8   | 9.6    |

\*Fuel economies for LDV's based on EPA memo from Karl H. Hellman to Ralph C. Stahman regarding Light-Duty MPG, June 15, 1984.

\*\*Fuel economies for LDT's drawn from the input data used to generate "The Highway Fuel Consumption Model: Tenth Quarterly Report," prepared by Energy and Environmental Analysis, Inc.

+Fuel economies for Heavy-duty gasoline vehicles (HDGV) were derived from figure presented in an EPA memo to Mark Wolcott from Cooper Smith, dated July 2, 1984.

++Pre-1986 fuel economies are composites of HDGV1 and HDGV2.

TABLE 2-7  
FUEL ECONOMY CORRECTION FACTORS AT VARIOUS SPEEDS,  $C_s$   
(Normalized to 32.7 miles/hour-cyclic driving)

|       | <u>Speed (mph)</u> | $C_s$                 | $C_s$                |
|-------|--------------------|-----------------------|----------------------|
|       |                    | <u>Cyclic Driving</u> | <u>Steady Cruise</u> |
|       | 5                  | 0.323                 | 0.467                |
|       | 10                 | 0.553                 | 0.709                |
|       | 15                 | 0.692                 | 0.997                |
| (FTP) | 20                 | 0.790                 | 1.153                |
|       | 25                 | 0.885                 | 1.248                |
|       | 30                 | 0.963                 | 1.294                |
|       | 32.7               | 1.000                 | 1.303                |
| (SET) | 35                 | 1.022                 | 1.303                |
|       | 40                 | 1.053                 | 1.288                |
|       | 45                 | 1.073                 | 1.256                |
|       | 50                 | 1.078                 | 1.210                |
|       | 55                 | 1.063                 | 1.159                |
|       | 60                 | 1.023                 | 1.104                |

TABLE 2-8  
FRACTION OF LIGHT-DUTY TRUCK I MODEL YEAR SALES EQUIPPED WITH  
DIFFERENT EMISSION CONTROL SYSTEMS (LOW-ALTITUDE NON-CALIFORNIA)

| System                       | Pre-<br>1975 | 1975 | 1976 | 1977 | 1978 | 1979 | 1980 | 1981 | 1982  | 1983  | 1984  | 1985  | 1986  | 1987  | 1988+ |
|------------------------------|--------------|------|------|------|------|------|------|------|-------|-------|-------|-------|-------|-------|-------|
| F <sub>L,2,j</sub>           | 1.000        | .188 | .088 | .038 | .027 | .03  | .021 | .026 | .021  | .022  | 0     | 0     | 0     | 0     | 0     |
| F <sub>2,j,NL,NOCAT</sub>    | 0            | .123 | .225 | .083 | .069 | .034 | .027 | .011 | 0     | 0     | 0     | 0     | 0     | 0     | 0     |
| F <sub>2,j,OXCAT/NOAIR</sub> | 0            | .570 | .504 | .596 | .605 | .561 | .564 | .574 | .066  | .092  | .003  | 0     | 0     | 0     | 0     |
| F <sub>2,j,OXCAT/AIR</sub>   | 0            | .307 | .271 | .321 | .325 | .405 | .409 | .415 | .887  | .687  | .595  | .550  | .550  | .150  | .150  |
| F <sub>2,j,3WCAT</sub>       | 0            | 0    | 0    | 0    | 0    | 0    | 0    | 0    | .027  | .054  | .126  | .150  | .150  | .350  | .350  |
| F <sub>2,j,3WCAT/OXCAT</sub> | 0            | 0    | 0    | 0    | 0    | 0    | 0    | 0    | .021  | .167  | .276  | .300  | .300  | .500  | .500  |
| F <sub>D,2,j</sub>           | 0            | .002 | .003 | .005 | .009 | .028 | .034 | .060 | .080  | .100  | .130  | .160  | .180  | .210  | .240  |
| F <sub>2,j,CAT</sub>         | 0            | .877 | .775 | .917 | .930 | .966 | .973 | .989 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 |
| F <sub>2,j,CAT/NOAIR</sub>   | 0            | .570 | .504 | .596 | .605 | .561 | .564 | .574 | .069  | .073  | .056  | .080  | .080  | .200  | .200  |
| F <sub>2,CAT/AIR</sub>       | 0            | .307 | .271 | .321 | .325 | .405 | .409 | .415 | .931  | .927  | .944  | .920  | .920  | .800  | .800  |

Sources: U.S. EPA Emission Factor In-Use Test Vehicle Data Base.  
U.S. EPA Fuel Economy Data Base.  
U.S. EPA Federal Register: Federal Certification Test Results 1975-78 and 1982-84.  
EEA Estimates of Emission Control Systems Projections.

Note: Model year columns do not add up to 1.000. Only F<sub>L,2,j</sub> and F<sub>D,2,j</sub> are fractions of all LDTIs. All other systems are fractions of all unleaded LDTIs.

TABLE 2-9  
FLEET SALES FRACTIONS  
Light-Duty Trucks I

| Model<br>Years | Unleaded Gasoline<br>Fraction of LDT1<br>Fleet, $F_{NL,2,j}^*$ | Leaded Gasoline<br>Fraction of LDT1<br>Fleet, $F_{L,2,j}$ | Diesel Fraction of<br>LDT1 Fleet, $F_{D,2,j}^{**}$ |
|----------------|----------------------------------------------------------------|-----------------------------------------------------------|----------------------------------------------------|
| Pre-1975       | 0.000                                                          | 1.000                                                     | 0.000                                              |
| 1975           | 0.810                                                          | 0.188                                                     | 0.002                                              |
| 1976           | 0.909                                                          | 0.088                                                     | 0.003                                              |
| 1977           | 0.957                                                          | 0.038                                                     | 0.005                                              |
| 1978           | 0.964                                                          | 0.027                                                     | 0.009                                              |
| 1979           | 0.942                                                          | 0.030                                                     | 0.028                                              |
| 1980           | 0.945                                                          | 0.021                                                     | 0.034                                              |
| 1981           | 0.914                                                          | 0.026                                                     | 0.060                                              |
| 1982           | 0.899                                                          | 0.021                                                     | 0.080                                              |
| 1983           | 0.878                                                          | 0.022                                                     | 0.100                                              |
| 1984           | 0.870                                                          | 0.000                                                     | 0.130                                              |
| 1985           | 0.840                                                          | 0.000                                                     | 0.160                                              |
| 1986           | 0.820                                                          | 0.000                                                     | 0.180                                              |
| 1987           | 0.790                                                          | 0.000                                                     | 0.210                                              |
| 1988           | 0.760                                                          | 0.000                                                     | 0.240                                              |
| 1989           | 0.730                                                          | 0.000                                                     | 0.270                                              |
| 1990           | 0.706                                                          | 0.000                                                     | 0.294                                              |
| 1991           | 0.697                                                          | 0.000                                                     | 0.303                                              |
| 1992           | 0.688                                                          | 0.000                                                     | 0.312                                              |
| 1993           | 0.679                                                          | 0.000                                                     | 0.321                                              |
| 1994           | 0.670                                                          | 0.000                                                     | 0.330                                              |
| 1995+          | 0.661                                                          | 0.000                                                     | 0.339                                              |

Where  $F_{NL,2}$  = Estimated fraction of the LDT1 model year fleet which use unleaded gasoline.

$F_{L,2}$  = Estimated fraction of the LDT1 model year fleet which use leaded gasoline.

$F_{D,2}$  = Estimated fraction of the LDT1 model year fleet which use diesel fuel.

\*Percentages of gasoline vehicles requiring leaded and unleaded fuel obtained from Energy and Environmental Analysis, Inc., "The Highway Fuel Consumption Model: Tenth Quarterly Report," November 1983.

\*\*Diesel and gasoline sales projections were derived from MOBILE3.

TABLE 2-10  
TRAVEL WEIGHTING FACTOR CALCULATION\*  
Light-Duty Gas Trucks I\*\*

| Vehicle<br>Age | (a)<br>January 1<br>Fraction<br>Total<br>Registration | (b)<br>Annual<br>Mileage<br>Accumulation<br>Rate | (a)(b)  | [(a)(b)/(SUM)]<br>Fraction of<br>LDV Travel by<br>Model Year, $m_{2,j,G}$ |
|----------------|-------------------------------------------------------|--------------------------------------------------|---------|---------------------------------------------------------------------------|
| 1              | 0.023                                                 | 17,394                                           | 400.1   | 0.036                                                                     |
| 2              | 0.089                                                 | 17,079                                           | 1,520.0 | 0.135                                                                     |
| 3              | 0.085                                                 | 15,839                                           | 1,346.3 | 0.120                                                                     |
| 4              | 0.081                                                 | 14,690                                           | 1,189.9 | 0.106                                                                     |
| 5              | 0.076                                                 | 13,624                                           | 1,035.4 | 0.092                                                                     |
| 6              | 0.072                                                 | 12,636                                           | 909.8   | 0.081                                                                     |
| 7              | 0.068                                                 | 11,719                                           | 796.9   | 0.071                                                                     |
| 8              | 0.064                                                 | 10,868                                           | 695.6   | 0.062                                                                     |
| 9              | 0.060                                                 | 10,080                                           | 604.8   | 0.054                                                                     |
| 10             | 0.055                                                 | 9,348                                            | 514.1   | 0.046                                                                     |
| 11             | 0.050                                                 | 8,670                                            | 433.5   | 0.039                                                                     |
| 12             | 0.046                                                 | 8,041                                            | 369.9   | 0.033                                                                     |
| 13             | 0.042                                                 | 7,457                                            | 313.2   | 0.028                                                                     |
| 14             | 0.038                                                 | 6,916                                            | 262.8   | 0.023                                                                     |
| 15             | 0.034                                                 | 6,415                                            | 218.1   | 0.019                                                                     |
| 16             | 0.029                                                 | 5,949                                            | 172.5   | 0.015                                                                     |
| 17             | 0.025                                                 | 5,517                                            | 137.9   | 0.012                                                                     |
| 18             | 0.021                                                 | 5,117                                            | 107.5   | 0.009                                                                     |
| 19             | 0.017                                                 | 4,746                                            | 80.7    | 0.007                                                                     |
| 20             | 0.025                                                 | 4,402                                            | 110.1   | 0.010                                                                     |

SUM: 11,219.1

\*Data derived from MOBILE3.

\*\*Light-duty trucks I have a gross vehicle weight (GVW) rating of 6,000 pounds or less.

TABLE 2-11  
FRACTION OF MODEL YEAR SALE OF LIGHT-DUTY TRUCKS II  
BY EMISSION CONTROL SYSTEMS

| System                       | Pre-<br>1975 | 1975  | 1976  | 1977  | 1978 | 1979 | 1980  | 1981  | 1982  | 1983  | 1984  | 1985  | 1986  | 1987  | 1988  |
|------------------------------|--------------|-------|-------|-------|------|------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| F <sub>L,3,j</sub>           | 1.000        | 1.000 | 1.000 | 1.000 | .988 | 0    | 0     | 0     | 0     | 0     | 0     | 0     | 0     | 0     | 0     |
| F <sub>3,j,NL,NOCAT</sub>    | 0            | 0     | 0     | 0     | 0    | .008 | 0     | 0     | 0     | 0     | 0     | 0     | 0     | 0     | 0     |
| F <sub>3,j,OXCAT</sub>       | 0            | 0     | 0     | 0     | 0    | .496 | .500  | .500  | .222  | .284  | 0     | 0     | 0     | 0     | 0     |
| F <sub>3,j,OXCAT/AIR</sub>   | 0            | 0     | 0     | 0     | 0    | .496 | .500  | .500  | .704  | .577  | .823  | .800  | .800  | 0     | 0     |
| F <sub>3,j,3WCAT</sub>       | 0            | 0     | 0     | 0     | 0    | 0    | 0     | 0     | 0     | .012  | .003  | 0     | 0     | .020  | .020  |
| F <sub>3,j,3WCAT/OXCAT</sub> | 0            | 0     | 0     | 0     | 0    | 0    | 0     | 0     | .074  | .127  | .174  | .200  | .200  | .980  | .980  |
| F <sub>D,3,j</sub>           | 0            | 0     | 0     | 0     | .012 | .025 | .050  | .050  | .080  | .113  | .147  | .180  | .194  | .208  | .222  |
| F <sub>3,j,CAT</sub>         | 0            | 0     | 0     | 0     | 0    | .992 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 |
| F <sub>3,j,CAT/NOAIR</sub>   | 0            | 0     | 0     | 0     | 0    | .496 | .500  | .500  | .222  | .293  | 0     | 0     | 0     | .020  | .020  |
| F <sub>3,CAT/AIR</sub>       | 0            | 0     | 0     | 0     | 0    | .496 | .500  | .500  | .778  | .707  | 1.000 | 1.000 | 1.000 | .980  | .980  |

Sources: U.S. EPA Emission Factor In-Use Test Vehicle Data Base.  
U.S. EPA Federal Register: Federal Certification Test Results 1982-84.  
EPA Estimates of Emission Control Systems Projections.

Note: Model year columns do not add up to 1.000. Only F<sub>L,3,j</sub> and F<sub>D,3,j</sub> are fractions of all LDT2s. All other systems are fractions of all unleaded LDT2s.

TABLE 2-12  
FLEET SALES FRACTIONS  
Light-Duty Trucks II

| Model<br>Years | Unleaded Gasoline<br>Fraction of LDT2<br>Fleet, $F_{NL,3,j*}$ | Leaded Gasoline<br>Fraction of LDT2<br>Fleet, $F_{L,3,j**}$ | Diesel Fraction of<br>LDT2 Fleet, $F_{D,3,j**}$ |
|----------------|---------------------------------------------------------------|-------------------------------------------------------------|-------------------------------------------------|
| Pre-1975       | 0.000                                                         | 1.000                                                       | 0.000                                           |
| 1975           | 0.000                                                         | 0.998                                                       | 0.002                                           |
| 1976           | 0.000                                                         | 0.997                                                       | 0.003                                           |
| 1977           | 0.000                                                         | 0.995                                                       | 0.005                                           |
| 1978           | 0.000                                                         | 0.991                                                       | 0.009                                           |
| 1979           | 0.972                                                         | 0.000                                                       | 0.028                                           |
| 1980           | 0.966                                                         | 0.000                                                       | 0.034                                           |
| 1981           | 0.940                                                         | 0.000                                                       | 0.060                                           |
| 1982           | 0.920                                                         | 0.000                                                       | 0.080                                           |
| 1983           | 0.900                                                         | 0.000                                                       | 0.100                                           |
| 1984           | 0.870                                                         | 0.000                                                       | 0.130                                           |
| 1985           | 0.840                                                         | 0.000                                                       | 0.160                                           |
| 1986           | 0.820                                                         | 0.000                                                       | 0.180                                           |
| 1987           | 0.790                                                         | 0.000                                                       | 0.210                                           |
| 1988           | 0.760                                                         | 0.000                                                       | 0.240                                           |
| 1989           | 0.730                                                         | 0.000                                                       | 0.270                                           |
| 1990           | 0.706                                                         | 0.000                                                       | 0.294                                           |
| 1991           | 0.697                                                         | 0.000                                                       | 0.303                                           |
| 1992           | 0.688                                                         | 0.000                                                       | 0.312                                           |
| 1993           | 0.679                                                         | 0.000                                                       | 0.321                                           |
| 1994           | 0.670                                                         | 0.000                                                       | 0.330                                           |
| 1995+          | 0.661                                                         | 0.000                                                       | 0.339                                           |

WHERE  $F_{NL,3}$  = Estimated fraction of the LDT2 model year fleet which use unleaded gasoline.

$F_{L,3}$  = Estimated fraction of the LDT2 model year fleet which use leaded gasoline.

$F_{D,3}$  = Estimated fraction of the LDT2 model year fleet which use diesel fuel.

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\*Percentages of gasoline vehicles requiring leaded and unleaded fuel obtained from Energy and Environmental Analysis, Inc., "The Highway Fuel Consumption Model: Tenth Quarterly Report," November 1983.

\*\*Diesel and gasoline sales projections were derived from MOBILE3.

TABLE 2-13  
TRAVEL WEIGHTING FACTOR CALCULATION\*  
Light-Duty Gas Trucks II\*\*

| Vehicle<br>Age | (a)<br>January 1<br>Fraction<br>Total<br>Registration | (b)<br>Annual<br>Mileage<br>Accumulation<br>Rate | (a)(b)  | [(a)(b)/(SUM)]<br>Fraction of<br>LDT2 Travel by<br>Model Year, $m_{3,j,G}$ |
|----------------|-------------------------------------------------------|--------------------------------------------------|---------|----------------------------------------------------------------------------|
| 1              | 0.023                                                 | 18,352                                           | 422.1   | 0.036                                                                      |
| 2              | 0.089                                                 | 18,001                                           | 1,602.1 | 0.138                                                                      |
| 3              | 0.085                                                 | 16,622                                           | 1,412.9 | 0.122                                                                      |
| 4              | 0.081                                                 | 15,348                                           | 1,243.2 | 0.107                                                                      |
| 5              | 0.076                                                 | 14,172                                           | 1,077.1 | 0.093                                                                      |
| 6              | 0.072                                                 | 13,087                                           | 942.3   | 0.081                                                                      |
| 7              | 0.068                                                 | 12,084                                           | 821.7   | 0.071                                                                      |
| 8              | 0.064                                                 | 11,158                                           | 714.1   | 0.062                                                                      |
| 9              | 0.060                                                 | 10,303                                           | 618.2   | 0.053                                                                      |
| 10             | 0.055                                                 | 9,514                                            | 523.3   | 0.045                                                                      |
| 11             | 0.050                                                 | 8,785                                            | 439.3   | 0.038                                                                      |
| 12             | 0.046                                                 | 8,112                                            | 373.2   | 0.032                                                                      |
| 13             | 0.042                                                 | 7,491                                            | 314.6   | 0.027                                                                      |
| 14             | 0.038                                                 | 6,917                                            | 262.8   | 0.023                                                                      |
| 15             | 0.034                                                 | 6,386                                            | 217.1   | 0.019                                                                      |
| 16             | 0.029                                                 | 5,897                                            | 171.0   | 0.015                                                                      |
| 17             | 0.025                                                 | 5,446                                            | 136.2   | 0.012                                                                      |
| 18             | 0.021                                                 | 5,028                                            | 105.6   | 0.009                                                                      |
| 19             | 0.017                                                 | 4,643                                            | 78.9    | 0.007                                                                      |
| 20+            | 0.025                                                 | 4,287                                            | 107.2   | 0.009                                                                      |

SUM: 11,582.9

\*Data derived from MOBILE3.

\*\*Light-duty trucks II have a gross vehicle weight (GVW) rating of 6,001 to 8,500 pounds.

TABLE 2-14

TRAVEL WEIGHTING FACTOR CALCULATION\*  
Light-Duty Diesel Trucks I and II\*\*

| Vehicle<br>Age | (a)<br>January 1<br>Fraction<br>Total<br>Registration | (b)<br>Annual<br>Mileage<br>Accumulation<br>Rate | (a)(b)  | [(a)(b)/(SUM)]<br>Fraction of<br>LDDT I & II Travel by<br>Model Year, $m_{i,j,D}$ |
|----------------|-------------------------------------------------------|--------------------------------------------------|---------|-----------------------------------------------------------------------------------|
| 1              | 0.023                                                 | 17,552                                           | 403.7   | 0.035                                                                             |
| 2              | 0.087                                                 | 17,230                                           | 1,499.0 | 0.129                                                                             |
| 3              | 0.083                                                 | 15,964                                           | 1,325.0 | 0.114                                                                             |
| 4              | 0.079                                                 | 14,791                                           | 1,168.5 | 0.101                                                                             |
| 5              | 0.075                                                 | 13,705                                           | 1,027.9 | 0.088                                                                             |
| 6              | 0.071                                                 | 12,699                                           | 901.6   | 0.078                                                                             |
| 7              | 0.066                                                 | 11,766                                           | 776.6   | 0.067                                                                             |
| 8              | 0.062                                                 | 10,901                                           | 675.9   | 0.058                                                                             |
| 9              | 0.058                                                 | 10,101                                           | 585.9   | 0.050                                                                             |
| 10             | 0.054                                                 | 9,359                                            | 505.4   | 0.043                                                                             |
| 11             | 0.049                                                 | 8,671                                            | 424.9   | 0.037                                                                             |
| 12             | 0.045                                                 | 8,035                                            | 361.6   | 0.031                                                                             |
| 13             | 0.041                                                 | 7,444                                            | 305.2   | 0.026                                                                             |
| 14             | 0.037                                                 | 6,897                                            | 255.2   | 0.022                                                                             |
| 15             | 0.033                                                 | 6,391                                            | 210.9   | 0.018                                                                             |
| 16             | 0.029                                                 | 5,921                                            | 171.7   | 0.015                                                                             |
| 17             | 0.025                                                 | 5,487                                            | 137.2   | 0.012                                                                             |
| 18             | 0.020                                                 | 5,084                                            | 101.7   | 0.009                                                                             |
| 19             | 0.016                                                 | 4,710                                            | 75.4    | 0.006                                                                             |
| 20+            | 0.025                                                 | 4,364                                            | 109.1   | 0.009                                                                             |

SUM: 11,622.4

\*Data derived from MOBILE3.

\*\*Light-duty trucks I and II have a gross vehicle weight (GVW) rating of 0-8,500 pounds.

TABLE 2-15  
FLEET SALES FRACTIONS  
Heavy-Duty Gasoline Vehicles (HDGV)\*

| <u>Model<br/>Years</u> | <u>Unleaded Fraction of<br/>HDGV Fleet <math>F_{NL,4,j}^{**}</math></u> | <u>Leaded Fraction of<br/>HDGV Fleet <math>F_{L,4,j}</math></u> |
|------------------------|-------------------------------------------------------------------------|-----------------------------------------------------------------|
| Pre-1977               | 0.000                                                                   | 1.000                                                           |
| 1977                   | 0.000                                                                   | 1.000                                                           |
| 1978                   | 0.000                                                                   | 1.000                                                           |
| 1979                   | 0.000                                                                   | 1.000                                                           |
| 1980                   | 0.000                                                                   | 1.000                                                           |
| 1981                   | 0.000                                                                   | 1.000                                                           |
| 1982                   | 0.000                                                                   | 1.000                                                           |
| 1983                   | 0.000                                                                   | 1.000                                                           |
| 1984                   | 0.000                                                                   | 1.000                                                           |
| 1985                   | 0.000                                                                   | 1.000                                                           |
| 1986                   | 0.000                                                                   | 1.000                                                           |
| 1987                   | 0.823                                                                   | 0.177                                                           |
| 1988                   | 0.824                                                                   | 0.176                                                           |
| 1989                   | 0.825                                                                   | 0.175                                                           |
| 1990                   | 0.826                                                                   | 0.174                                                           |
| 1991                   | 0.828                                                                   | 0.172                                                           |
| 1992                   | 0.829                                                                   | 0.171                                                           |
| 1993                   | 0.833                                                                   | 0.167                                                           |
| 1994                   | 0.837                                                                   | 0.163                                                           |
| 1995                   | 0.840                                                                   | 0.160                                                           |

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\*Heavy-duty gasoline vehicles have a gross vehicle weight (GVW) rating greater than 8,501 pounds.

\*The estimated fractions of the HDGV model year fleets which are gasoline-powered are consistent with figures from M.C. Smith, "Heavy-Duty Vehicle Emission Conversion Factors: 1962-1997," EPA-AA/SDSB-84-1, Office of Mobile Sources, August 1984.

TABLE 2-16

TRAVEL WEIGHTING FACTOR CALCULATION\*  
Heavy-Duty Gasoline Vehicle (HDGV)\*\*

| Vehicle<br>Age | (a)<br>January 1<br>Fraction<br>Total<br>Registration | (b)<br>Annual<br>Mileage<br>Accumulation<br>Rate | (a)(b)  | [(a)(b)/(SUM)]<br>Fraction of<br>HDGT Travel by<br>Model Year, $m_{4,j,G}$ |
|----------------|-------------------------------------------------------|--------------------------------------------------|---------|----------------------------------------------------------------------------|
| 1              | 0.000                                                 | 0                                                | 0.0     | 0.000                                                                      |
| 2              | 0.148                                                 | 19,967                                           | 2,955.1 | 0.227                                                                      |
| 3              | 0.126                                                 | 18,077                                           | 2,277.7 | 0.175                                                                      |
| 4              | 0.107                                                 | 16,365                                           | 1,751.1 | 0.134                                                                      |
| 5              | 0.092                                                 | 14,815                                           | 1,363.0 | 0.105                                                                      |
| 6              | 0.078                                                 | 13,413                                           | 1,046.2 | 0.080                                                                      |
| 7              | 0.067                                                 | 12,143                                           | 813.6   | 0.062                                                                      |
| 8              | 0.058                                                 | 10,993                                           | 637.6   | 0.049                                                                      |
| 9              | 0.049                                                 | 9,952                                            | 487.6   | 0.037                                                                      |
| 10             | 0.041                                                 | 9,010                                            | 369.4   | 0.028                                                                      |
| 11             | 0.036                                                 | 8,156                                            | 293.6   | 0.023                                                                      |
| 12             | 0.030                                                 | 7,384                                            | 221.5   | 0.017                                                                      |
| 13             | 0.026                                                 | 6,685                                            | 173.8   | 0.013                                                                      |
| 14             | 0.022                                                 | 6,052                                            | 133.1   | 0.010                                                                      |
| 15             | 0.020                                                 | 5,479                                            | 121.0   | 0.009                                                                      |
| 16             | 0.016                                                 | 4,960                                            | 79.4    | 0.006                                                                      |
| 17             | 0.014                                                 | 4,490                                            | 62.9    | 0.005                                                                      |
| 18             | 0.012                                                 | 4,065                                            | 48.8    | 0.004                                                                      |
| 19             | 0.010                                                 | 3,680                                            | 36.8    | 0.003                                                                      |
| 20+            | 0.049                                                 | 3,332                                            | 163.3   | 0.013                                                                      |

SUM: 13,035.5

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\*Data derived from MOBILE3.

\*\*Heavy-duty gasoline vehicles have a gross vehicle weight (GVW) rating greater than 8,500 pounds.

TABLE 2-17  
TRAVEL WEIGHTING FACTOR CALCULATION\*  
For Heavy-Duty Diesel Vehicles in Calendar Year 1987

| Vehicle Age | (a)<br>January 1<br>Fraction<br>Total<br>Registration | (b)**<br>Annual<br>Mileage<br>Accumulation<br>Rate | (a)(b)   | $\frac{(a)(b)}{(\text{SUM})}$<br>Fraction of<br>HDTT 1 Travel by<br>Model Year, $m_{5,j,D}$ |
|-------------|-------------------------------------------------------|----------------------------------------------------|----------|---------------------------------------------------------------------------------------------|
| 1           | 0.000                                                 | 0                                                  | 0.0      | 0.000                                                                                       |
| 2           | 0.166                                                 | 67,910                                             | 11,273.1 | 0.241                                                                                       |
| 3           | 0.13                                                  | 61,749                                             | 8,521.4  | 0.182                                                                                       |
| 4           | 0.115                                                 | 56,155                                             | 6,457.8  | 0.138                                                                                       |
| 5           | 0.097                                                 | 51,073                                             | 4,954.1  | 0.106                                                                                       |
| 6           | 0.080                                                 | 46,457                                             | 3,716.6  | 0.079                                                                                       |
| 7           | 0.067                                                 | 42,260                                             | 2,831.4  | 0.060                                                                                       |
| 8           | 0.056                                                 | 38,447                                             | 2,153.0  | 0.046                                                                                       |
| 9           | 0.047                                                 | 34,982                                             | 1,644.2  | 0.035                                                                                       |
| 10          | 0.040                                                 | 31,832                                             | 1,273.3  | 0.027                                                                                       |
| 11          | 0.033                                                 | 28,968                                             | 955.9    | 0.020                                                                                       |
| 12          | 0.027                                                 | 26,363                                             | 711.8    | 0.015                                                                                       |
| 13          | 0.023                                                 | 23,995                                             | 551.9    | 0.012                                                                                       |
| 14          | 0.019                                                 | 21,43                                              | 415.0    | 0.009                                                                                       |
| 15          | 0.015                                                 | 19,883                                             | 298.2    | 0.006                                                                                       |
| 16          | 0.013                                                 | 18,101                                             | 235.3    | 0.005                                                                                       |
| 17          | 0.011                                                 | 16,41                                              | 181.3    | 0.004                                                                                       |
| 18          | 0.009                                                 | 15,007                                             | 135.1    | 0.003                                                                                       |
| 19          | 0.008                                                 | 13,665                                             | 109.3    | 0.002                                                                                       |
| 20+         | 0.034                                                 | 12,444                                             | 423.1    | 0.009                                                                                       |

SUM: 46,841.8

\*Data derived from MOBILE3.

\*\*The tabulated annual mileage accumulation rate is specific to CY 1987 only. The rate shifts from one year to the next due to the increasing penetration of diesels in the lower mileage, lighter weight classes of the heavy-duty truck category (which contains all vehicles with a GVW rating over 8,500 pounds).

TABLE 2-18  
TRAVEL WEIGHTING FACTOR CALCULATION\*  
Motorcycles

| Vehicle<br>Age | (a)<br>January 1<br>Fraction<br>Total<br>Registration | (b)<br>Annual<br>Mileage<br>Accumulation<br>Rate | (a)(b) | [(a)(b)/(SUM)]<br>Fraction of<br>MC Travel by<br>Model Year, $m_{6,j,G}$ |
|----------------|-------------------------------------------------------|--------------------------------------------------|--------|--------------------------------------------------------------------------|
|                |                                                       |                                                  |        |                                                                          |
| 1              | 0.000                                                 | 0                                                | 0.0    | 0.000                                                                    |
| 2              | 0.167                                                 | 4,100                                            | 685.7  | 0.356                                                                    |
| 3              | 0.159                                                 | 2,800                                            | 445.7  | 0.232                                                                    |
| 4              | 0.134                                                 | 2,100                                            | 281.0  | 0.146                                                                    |
| 5              | 0.142                                                 | 1,600                                            | 227.0  | 0.118                                                                    |
| 6              | 0.131                                                 | 1,200                                            | 157.8  | 0.082                                                                    |
| 7              | 0.080                                                 | 800                                              | 63.7   | 0.033                                                                    |
| 8              | 0.051                                                 | 600                                              | 30.4   | 0.016                                                                    |
| 9              | 0.028                                                 | 400                                              | 11.1   | 0.001                                                                    |
| 10             | 0.010                                                 | 200                                              | 2.1    | 0.010                                                                    |
| 11             | 0.098                                                 | 200                                              | 19.6   | 0.000                                                                    |
| 12             | 0.000                                                 | 200                                              | 0.0    | 0.000                                                                    |
| 13             | 0.000                                                 | 0                                                | 0.0    | 0.000                                                                    |
| 14             | 0.000                                                 | 0                                                | 0.0    | 0.000                                                                    |
| 15             | 0.000                                                 | 0                                                | 0.0    | 0.000                                                                    |
| 16             | 0.000                                                 | 0                                                | 0.0    | 0.000                                                                    |
| 17             | 0.000                                                 | 0                                                | 0.0    | 0.000                                                                    |
| 18             | 0.000                                                 | 0                                                | 0.0    | 0.000                                                                    |
| 19             | 0.000                                                 | 0                                                | 0.0    | 0.000                                                                    |
| 20+            | 0.000                                                 | 0                                                | 0.0    | 0.000                                                                    |

SUM: 1,924.0

\*Data derived from MOBILE3.

TABLE 2-19  
RATES OF MISFUELING ( $r_i$ )  
FOR DIFFERENT VEHICLE CLASSES\*

|                                      | <u>I/M</u> | <u>Non-I/M</u> |
|--------------------------------------|------------|----------------|
| Light-Duty Vehicles (i=1)            | 0.09       | 0.20           |
| Light-Duty Trucks I (i=2)            | 0.20       | 0.46           |
| Light-Duty Trucks II (i=3)           | 0.21       | 0.47           |
| Heavy-Duty Gasoline Vehicles (i=4)** | 0.19       | 0.40           |
| Motorcycles (i=6)                    | 0          | 0              |

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\*Values in this table are expressed as fractions of the total number of vehicles in each class. Misfueling rates are determined for the weighted average mileage accumulated for each vehicle class.

\*\*Misfueling rates for Heavy-Duty Gasoline Vehicles pertain only to heavy-duty gasoline vehicles 1 made after model year 1986.

SOURCES: The equations used to estimate misfueling as a function of mileage for I/M and non-I/M areas are drawn from "Anti-Tampering and Anti-Misfueling Programs to Reduce In-Use Emissions from Motor Vehicles," EPA-AA-TSS-83-10, Office of Mobile Sources, December 31, 1983.

Weighted average mileages by vehicle category are calculated from data contained in MOBILE3.

TABLE 2-19a

RATES OF MISFUELING ( $r_1$ ) FOR DIFFERENT VEHICLE AGES AND CLASSES\*

| Vehicle Age | LDV     |     | LDTI    |     | LDTII   |     | HDGV1   |     |
|-------------|---------|-----|---------|-----|---------|-----|---------|-----|
|             | Non-I/M | I/M | Non-I/M | I/M | Non-I/M | I/M | Non-I/M | I/M |
| 1           | .04     | .04 | .22     | .13 | .23     | .13 | .18     | .12 |
| 2           | .07     | .05 | .27     | .14 | .27     | .15 | .23     | .13 |
| 3           | .10     | .06 | .31     | .16 | .32     | .16 | .28     | .15 |
| 4           | .13     | .07 | .35     | .17 | .36     | .17 | .32     | .16 |
| 5           | .16     | .08 | .38     | .18 | .39     | .18 | .36     | .17 |
| 6           | .18     | .09 | .42     | .19 | .43     | .19 | .39     | .18 |
| 7           | .21     | .09 | .45     | .20 | .46     | .20 | .42     | .19 |
| 8           | .23     | .10 | .47     | .21 | .49     | .21 | .45     | .20 |
| 9           | .25     | .11 | .50     | .21 | .51     | .22 | .48     | .21 |
| 10          | .27     | .11 | .52     | .22 | .54     | .23 | .50     | .22 |
| 11          | .29     | .12 | .55     | .23 | .56     | .23 | .52     | .22 |
| 12          | .31     | .12 | .57     | .24 | .58     | .24 | .54     | .23 |
| 13          | .33     | .13 | .59     | .24 | .60     | .25 | .56     | .23 |
| 14          | .34     | .13 | .60     | .25 | .62     | .25 | .57     | .24 |
| 15          | .36     | .14 | .62     | .25 | .63     | .26 | .59     | .24 |
| 16          | .37     | .14 | .64     | .26 | .65     | .26 | .60     | .25 |
| 17          | .39     | .15 | .65     | .26 | .66     | .26 | .61     | .25 |
| 18          | .40     | .15 | .66     | .26 | .68     | .27 | .62     | .25 |
| 19          | .41     | .15 | .68     | .27 | .69     | .27 | .63     | .25 |
| 20+         | .42     | .16 | .69     | .27 | .70     | .28 | .64     | .26 |

\*Values in this table are expressed as fractions of the total number of vehicles in each class. Misfueling rates are determined for the average mileage in each class. Misfueling rates are determined for the average mileage accumulated by each vehicle class of each vehicle age group.

\*\*Misfueling rates for Heavy-Duty Gasoline Vehicles 1 (HDGV1) are estimates for 1987 and later calendar years. Currently all HDGV1s use leaded fuel. (For example, for the year 1990, use the first three values in either the non-I/M or I/M HDGV1 column. All HDGV1s greater than 3 years old in this case (i.e., pre-1987 vehicles) would have a misfueling rate of zero since they do not require use of unleaded fuel.

SOURCES: The equations used to estimate misfueling as a function of mileage for I/M and non-I/M areas are drawn from "Anti-Tampering and Anti-Misfueling Programs to Reduce In-Use Emissions from Motor Vehicles," EPA-AA-TSS-83-10, Office of Mobile Sources, December 31, 1983.

Weighted average mileages by vehicle category are calculated from data contained in MOBILE3.

TABLE 2-20  
AVERAGE DATA ON PARTICLE SIZE DISTRIBUTION

| <u>Leaded Fuel, <math>M_L</math></u> | <u>Cumulative Fraction of Particulate<br/>Mass Smaller Than Diameter</u> |                           |                            |
|--------------------------------------|--------------------------------------------------------------------------|---------------------------|----------------------------|
|                                      | <u>0.2 <math>\mu</math></u>                                              | <u>2 <math>\mu</math></u> | <u>10 <math>\mu</math></u> |
| Median Particle Fractions, $M_L$     | 0.23                                                                     | 0.43                      | 0.64                       |
| Ranges of $M_L$ Values*              | 0.18-0.28                                                                | 0.28-0.58                 | 0.45-0.84                  |

References: (author summary of) Ninomiya et al, 1970; Moran et al, 1971; Gentel et al, 1973; Cantwell et al, 1972; Boyer and Laitiner, 1975; Habibi et al, 1970; Hirschler and Gilbert, 1964.

| <u>Unleaded Fuel, <math>M_{NL}</math></u> | <u>Cumulative Fraction of Particulate<br/>Mass Smaller Than Diameter</u> |                           |                            |
|-------------------------------------------|--------------------------------------------------------------------------|---------------------------|----------------------------|
|                                           | <u>0.2 <math>\mu</math></u>                                              | <u>2 <math>\mu</math></u> | <u>10 <math>\mu</math></u> |
| $M_{NL,C}$                                | 0.87                                                                     | 0.89                      | 0.97                       |
| Ranges of $M_{NL,C}$ Valves**             | 0.86-0.88                                                                | 0.84-0.94                 | 0.84-1.00                  |
| $M_{NL,NC}$                               | 0.42                                                                     | 0.66                      | 0.90                       |
| Ranges of $M_{NL,C}$ Valves               | 0.29-0.55                                                                | 0.52-0.80                 | 0.63-1.00                  |

References: (author summary of) Foster et al, 1976; Trayser et al, 1976; Foster et al, 1974; Melton et al, 1973; Habibi, 1973; Gentel et al, 1973.

\*95 percent confidence intervals on mean of data.

\*\*95 percent confidence intervals by "t" statistics.

TABLE 2-20  
AVERAGE DATA ON PARTICLE SIZE DISTRIBUTION (cont'd)

| Diesel Fuel, $M_D$        | Cumulative Fraction of Particulate<br>Mass Smaller Than Diameter |                             |                             |                             |                            |
|---------------------------|------------------------------------------------------------------|-----------------------------|-----------------------------|-----------------------------|----------------------------|
|                           | <u>0.2 <math>\mu</math></u>                                      | <u>1.0 <math>\mu</math></u> | <u>2.0 <math>\mu</math></u> | <u>2.5 <math>\mu</math></u> | <u>10 <math>\mu</math></u> |
| $M_D$                     | 0.73                                                             | 0.86                        | 0.90                        | 0.92                        | 1.00                       |
| Ranges of $M_D$<br>Values | 0.69-0.75                                                        | 0.76-0.93                   | 0.86-0.95                   | 0.88-0.95                   | 0.97-1.00                  |

References: Breslin, et al, 1976; Hare, 1979, Bykowski, 1981; Bykowski, 1983; McCain and Faulkner, 1979; Vuk, et al, 1976; Begeman, 1979; Carpenter and Johnson, 1979; Verrant and Kittelson, 1977.

| Brake Wear<br>Particulate, $M_B$         | Cumulative Fraction of Particulate<br>Mass Smaller Than Diameter |                             |                             |                           |                            |
|------------------------------------------|------------------------------------------------------------------|-----------------------------|-----------------------------|---------------------------|----------------------------|
|                                          | <u>0.43 <math>\mu</math></u>                                     | <u>1.1 <math>\mu</math></u> | <u>4.7 <math>\mu</math></u> | <u>7 <math>\mu</math></u> | <u>10 <math>\mu</math></u> |
| Median Particle<br>Fractions, $M_B^{++}$ | 0.09                                                             | 0.16                        | 0.82                        | 0.90                      | 0.98                       |
| Ranges of $M_B$<br>Values                | Not available                                                    |                             |                             |                           |                            |

Reference: Cha et al, 1983.

<sup>+</sup> Intermediate speed, no load, prechamber engine, 2D fuel.

<sup>++</sup> Samples for determining particle size distribution were collected by running about 20 braking cycles weighted to be representative of urban driving conditions.

TABLE 2-21  
LOW ALTITUDE HDDV CONVERSION FACTORS\*

| <u>Model Year</u> | <u>Conversion Factor (CF<sub>j</sub>)</u> |
|-------------------|-------------------------------------------|
| 1951-1962         | 2.7420                                    |
| 1963-1965         | 2.7307                                    |
| 1966-1968         | 2.8267                                    |
| 1969-1971         | 3.0080                                    |
| 1972-1974         | 3.1917                                    |
| 1975-1979         | 3.1420                                    |
| 1980-1981         | 2.7780                                    |
| 1982-1984         | 2.5580                                    |
| 1985              | 2.4700                                    |
| 1986              | 2.4260                                    |
| 1987-1992         | 2.3600                                    |
| 1993-1996         | 2.3175                                    |
| 1997-2000         | 2.3100                                    |

---

\*These factors are used to convert emissions in g/Bhp-hr to g/mile. They are consistent with those contained in M.C. Smith, "Heavy-Duty Vehicle Emission Conversion Factors: 1962-1977," EPA-AA-SDSB-84-1, Office of Mobile Sources, August 1984.

TABLE 2-22  
FRACTION OF LEAD BURNED THAT IS EMITTED,  $a_s$

|           | <u><math>a_{s1,j*}</math></u> |           | <u><math>a_{s2,j**}</math></u> |
|-----------|-------------------------------|-----------|--------------------------------|
| All years | .75                           | 1975-1980 | .40                            |
|           |                               | 1981+     | .44                            |

---

\* $a_{s1,j}$  is used for all vehicles using unleaded gasoline and for vehicles without catalysts using leaded gasoline.

\*\* $a_{s2,j}$  is used for catalyst equipped vehicles using leaded gasoline.

TABLE 2-23  
FRACTION OF CATALYST EQUIPPED VEHICLES WITH CATALYST REMOVED,  $P_i$ \*

|         | <u><math>P_1</math></u> | <u><math>P_2</math> and <math>P_3</math></u> |
|---------|-------------------------|----------------------------------------------|
| I/M     | .017                    | .050                                         |
| Non-I/M | .045                    | .195                                         |

---

\*Fractions obtained from "Anti-Tampering and Anti-Misfueling Programs to Reduce In-Use Emissions From Motor Vehicles," U.S. EPA, December 1983.

Figure 2-1

# LEADED GASOLINE PARTICULATE SIZE DISTRIBUTION

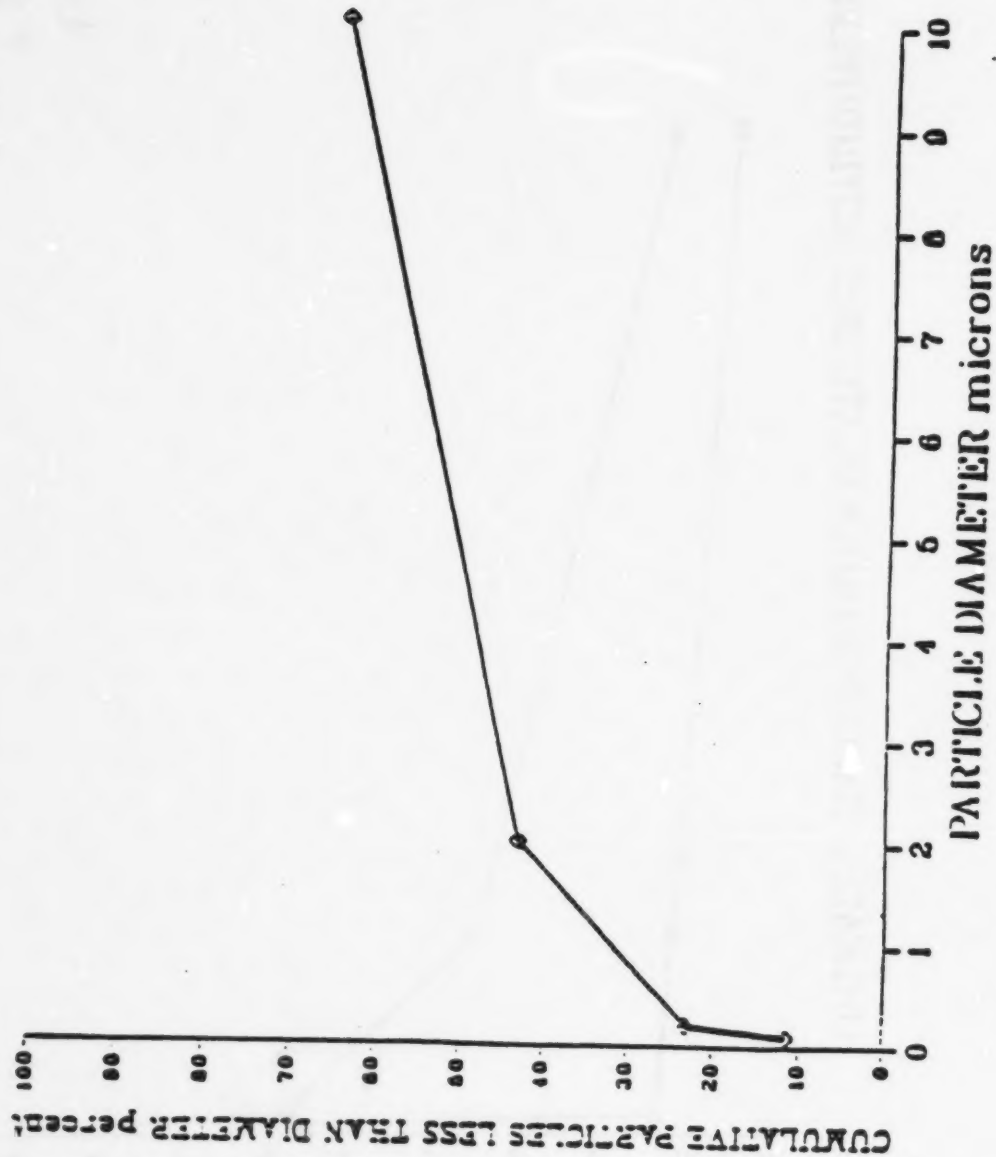


Figure 2-2

# UNLEADED GASOLINE PARTICULATE SIZE DISTRIBUTION

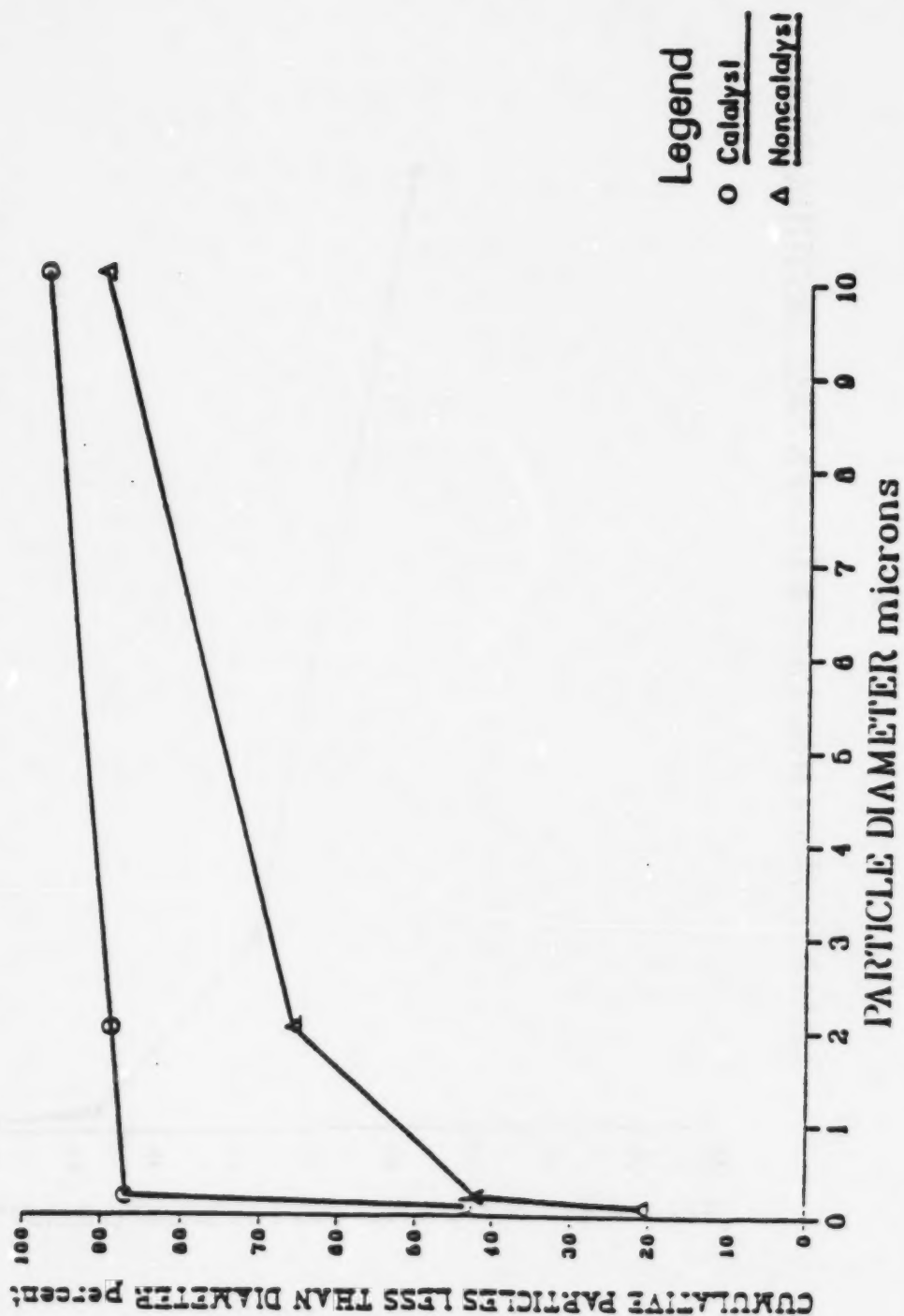


Figure 2-3

# DIESEL PARTICULATE SIZE DISTRIBUTION

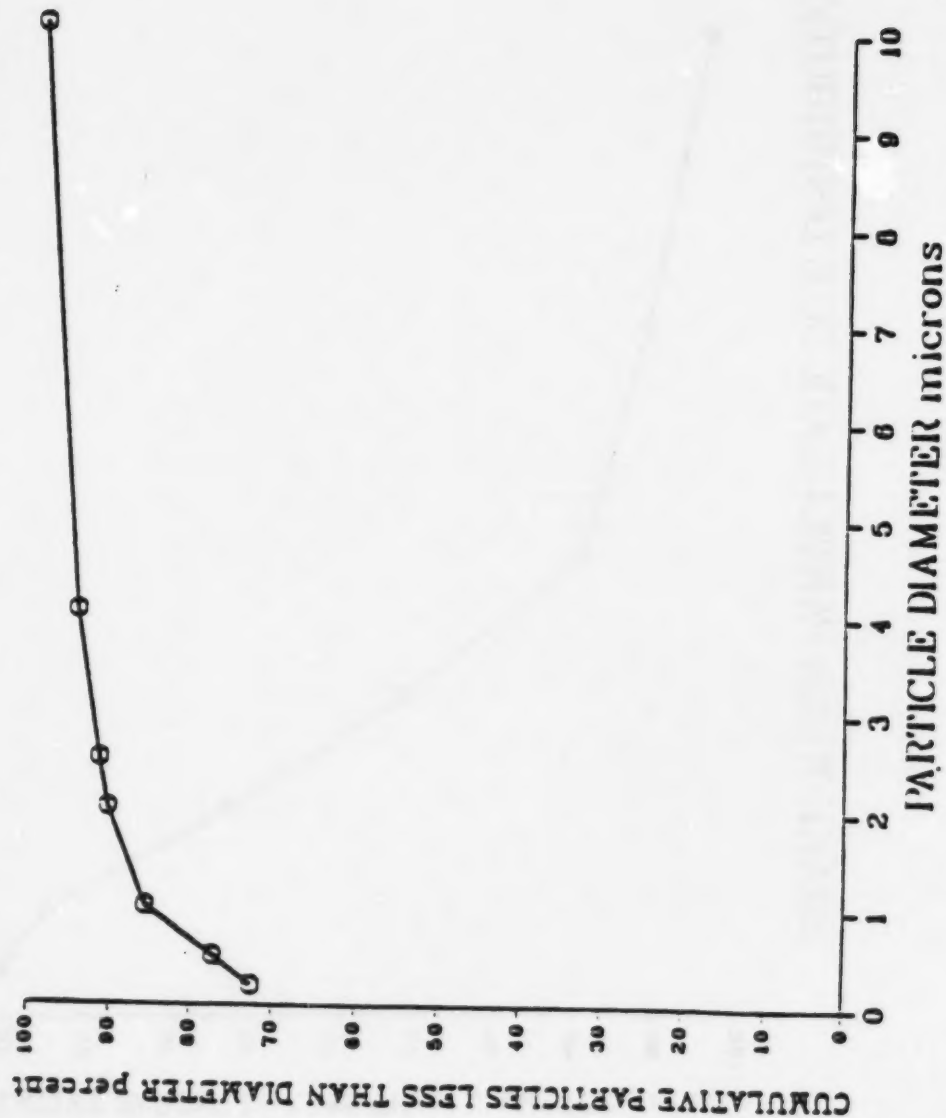
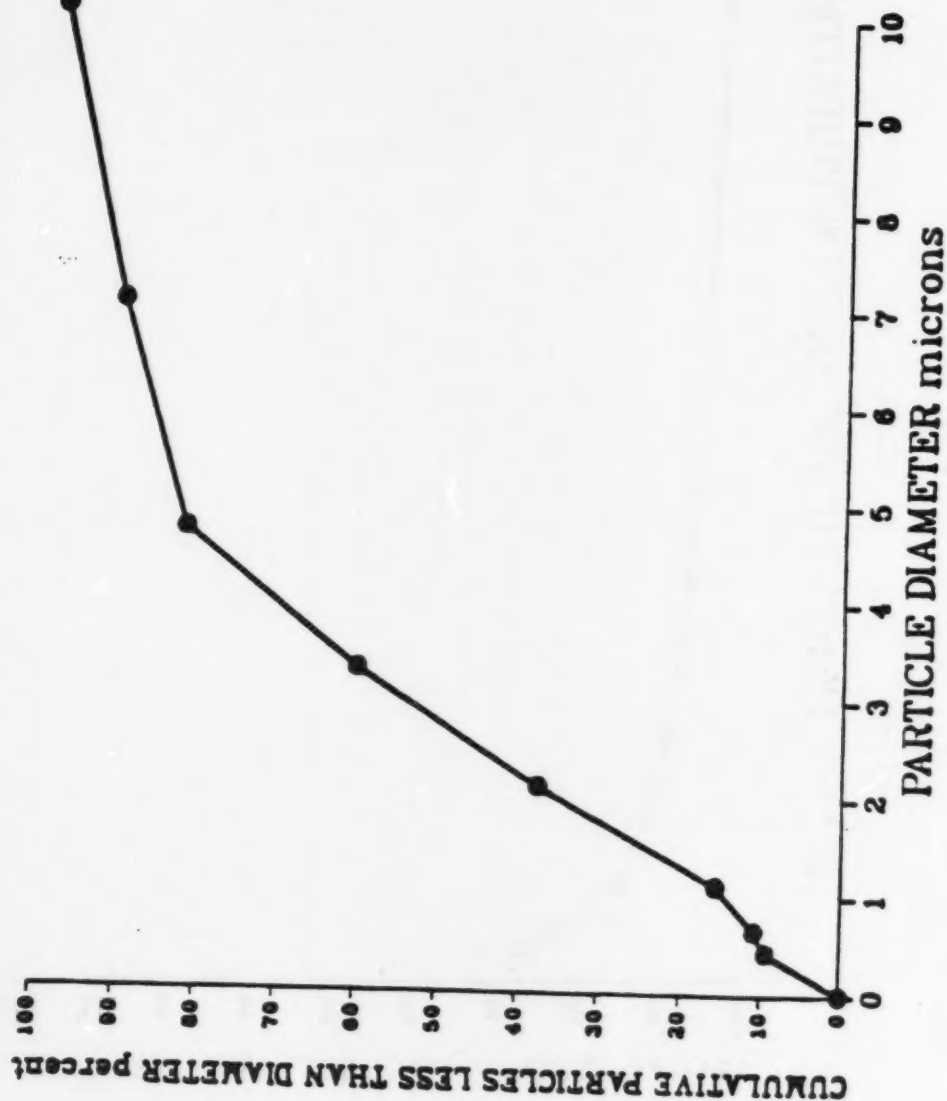


Figure 2-4

# BRAKE WEAR PARTICULATE SIZE DISTRIBUTION



### 3. EXAMPLE CALCULATION OF AUTOMOBILE PARTICULATE EMISSIONS LESS THAN 10 MICRONS

#### PROBLEM

For an area characterized by light-duty vehicles driving under cyclic conditions with an average speed of 19.6 miles per hour, calculate the particulate emission rate of particles less than  $10\ \mu$  in diameter for the year 1985. Assume an inspection and maintenance program has been implemented in this area. The simplified misfueling rates from Table 2-19 will be used.

#### SOLUTION

Use equations (2-1), (2-2), (2-3), (2-4), (2-5), (2-6), (2-7), (2-8), (2-9), (2-10), (2-12), (2-14), and (2-15).

Particulate Matter Size Cutoff =  $10\ \mu$

$n=1985$   $i=1=LDV$   $s=19.6$  mph  $M_B=0.98$

$t_{1,1985} = 1.0$   $r_i$  (from Table 2-19) = 0.09

---

Base Equation (2-1): Total Particulate Emission Factors  
Vehicle Exhaust Particulate Component and Airborne Brake  
Wear Component and Airborne Tire Wear Component

$$EF_{PM10,1985,19.6} = (1.0)(EF_{1,1985,19.6}) + (0.0128)(0.98) + (0.002)$$

---

Total Vehicle Exhaust Particulate Emission Component (2-2)\*:

$$EF_{1,1985,19.6} = \sum_{j=1966}^{1985} \left[ (EF_{1,1985,19.6}) + EF_{1,j,k_2,L} + EF_{1,j,k_3,L} \right. \\ \left. \times (F_{L,1,j}) + (EF_{1,j,k_1,1985,NL} + EF_{1,j,k_2,NL} + EF_{1,j,k_3,NL}) \right. \\ \left. \times (F_{NL,1,j}) \right] M_{i,j,G} + (EF_{1,j,D})(F_{D,1,j}) m_{1,j,D}$$

where  $Pb_{L,1985} = 1.1 \text{ (g/gal)}$

$Pb_{NL,1985} = 0.014 \text{ (g/gal)}$

$M_{L,10} = 0.64$

$M_{NL,C,10} = 0.97$

$M_{NL,C,10} = 0.90$

$M_D = 1.00$

$a_s = \text{from Table 2-22}$

$C_s = 0.79$

$P_i = 0.017$

Using the following equations to plug into Equation (2-2) and sum over the appropriate model years:

Lead Emission Factor Component (2-3a): Lead Fuel

For  $j=1966-1970 \quad k=1$

$$EF_{1,j,k_1,1985,L} = \left[ (1.1)(.887)(0.64) + (0.014)(0.113)(0.90) \right] \\ \times \frac{(0.75)(1.557)}{(E_{cl,j})(0.79)} = \frac{.925}{E_{c,i,j}}$$

---

\*The numbers in ( ) in equation titles refer to the equations presented in Section 2.

Lead Emission Factor Component (2-3b): Leaded Fuel

For j=1971-1974 k=1

$$EF_{1,j,k_1,1985,L} = \left[ (1.1)(.916)(0.64) + (0.014)(0.084)(0.90) \right] \\ \times \frac{(0.75)(1.557)}{(E_{c,i,j})(0.79)} = \frac{.955}{E_{c,i,j}}$$

---

Lead Emission Factor Component (2-4): Leaded Fuel

For j=1975-1985 k=1

$$EF_{1,j,k_1,1985,L} = \left[ (1.1)(0.724)(0.64) + (0.014)(0.276)(0.90) \right] \\ \times \frac{(0.75)(1.557)}{(E_{c,i,j})(0.79)} = \frac{.7586}{E_{c,i,j}}$$

---

Lead Emission Factor Component (2-5): Unleaded Fuel

For j=1975-1985 k=1

$$EF_{1,j,k_1,1985,NL} = \left[ (0.014)(0.91)(0.97)(0.75) \right. \\ \left. + (1.1)(0.09)(0.64) \left( F_{i,j,NL,NOCAT} + (0.17) \right. \right. \\ \left. \left. (F_{i,j,NL,CAT}) \right) (0.75) \right. \\ \left. + (1.1)(0.09)(0.64)(.983)(F_{i,j,NL,CAT})(a_{s2,j}) \right] \\ \times \frac{1.557}{E_{c,l,j}(0.79)} \\ = 1.557 \left[ \frac{(.009) + F_{i,j,NL,NOCAT} + (.017)(F_{i,j,NL,CAT})(.048) + (.062)F_{i,j,NL,CAT}(a_{s2,j})}{E_{c,l,j}(0.79)} \right] \\ = \frac{X_{,j}}{E_{c,i,j}}$$

|      | <u>X, j</u> |
|------|-------------|
| 1985 | .0731       |
| 1984 | .0731       |
| 1983 | .0731       |
| 1982 | .0731       |
| 1981 | .0731       |
| 1980 | .0682       |
| 1979 | .0682       |
| 1978 | .0682       |
| 1977 | .0682       |
| 1976 | .0694       |
| 1975 | .0717       |

---

Organic Emission Factor Component (2-6): Leaded Fuel

For j=1966-1969 k=2

$$EF_{1,j,k_2,L} = (0.193)(0.64) = 0.124 \text{ (g/mile)}$$


---

Organic Emission Factor Components (2-7): Leaded Fuel

For j=1970-1974 k=2

$$EF_{1,j,k_2,L} = (0.068)(0.64) = 0.044 \text{ (g/mile)}$$


---

Organic Emission Factor Component (2-8): Leaded Fuel

For j=1975-1985 k=2

$$EF_{1,j,k_2,L} = (0.030)(0.64) = 0.019 \text{ (g/mile)}$$


---

Organic Emission Factor Component (2-9): Unleaded Fuel

For j=1975-1985 k=2

$$\begin{aligned} EF_{1,j,k_2,NL} &= (0.91)(F_{i,j,CAT})(0.017)(0.97) \\ &+ (0.09)(F_{1,j,CAT})(0.068)(0.64) \\ &+ (F_{1,j,NL,NOCAT})(0.030)(0.90) \\ &= (0.019)(F_{1,j,CAT}) + (0.027)(F_{1,j,NL,NOCAT}) \end{aligned}$$

---

Sulfate Emission Factor Component (2-10): Leaded Fuel

For j=1966-1985 k=3

$$EF_{1,j,k_3,L} = (0.002)(0.64) = 0.001 \text{ (g/mile)}$$

---

Sulfate Emission Factor Component (2-12): Unleaded Fuel

For j=1975-1985 k=3

$$\begin{aligned} EF_{1,j,k_3,NL} &= (0.91) \left[ (F_{1,j,CAT/NOAIR})(0.005)(0.97) \right. \\ &+ (F_{1,j,CAT/AIR})(0.016)(0.97) \\ &+ (F_{1,j,NL,NOCAT})(0.002)(0.90) \left. \right] + (0.09)(0.002)(0.64) \\ &= \left[ (F_{1,j,CAT/NOAIR})(0.004) + (F_{1,j,CAT/AIR})(0.016) \right. \\ &+ (F_{1,j,NL,NOCAT})(0.002) \left. \right] + 0.0001 \end{aligned}$$

---

Diesel Particulate Emission Factor Component (2-14)

For j=1966-1980

$$EF_{1,j,D} = (0.700)(1.00) = 0.700 \text{ (g/mile)}$$

---

Diesel Particulate Emission Factor Component (2-15)

For j=1981-1985

$$EF_{1,j,D} = (0.300)(1.00) = 0.300 \text{ (g/mile)}$$

Table 3-1 presents the inputs and the sequence of calculations necessary to derive the LDV exhaust particulate emission factor components (using the above equations) and the total LDV exhaust particulate emission rate,  $EF_{1,1985,19.6}$ . This estimate is then combined with the airborne brake wear and airborne tire wear particulate components to obtain the total LDV particulate emission rate:

$$EF_{PM10,1985,19.6} = (1.0)(0.0581) + 0.0125 + 0.002 = 0.0726 \text{ (g/mile)}$$

This example is an estimate of particulate emissions from light-duty vehicles only. Therefore, the total emission rate from all vehicle classes for an area in calendar year 1985 can be expected to be considerably higher.

TABLE 3-1  
EXAMPLE CALCULATIONS  
LIGHT-DUTY VEHICLE PARTICULATE EMISSION RATE  
LESS THAN 10 MICRONS FOR THE YEAR 1985

A. Emission Factor Component Calculation Inputs

| Model<br>Year | Age | $m_{1,j}$ | $F_{NL,1,j}$ | $F_{L,1,j}$ | $E_{cl,1,j}$ | $F_{D,1,j}$ | $F_{1,j,CAT}$ | $F_{1,j,NL,NOCAT}$ | $F_{1,j,CAT/NOAIR}$ | $F_{1,j,CAT/AIR}$ |
|---------------|-----|-----------|--------------|-------------|--------------|-------------|---------------|--------------------|---------------------|-------------------|
| 1985          | 1   | 0.038     | 0.934        | -           | 24.6         | 0.066       | 1.000         | -                  | 0.381               | 0.691             |
| 1984          | 2   | 0.142     | 0.940        | -           | 23.8         | 0.060       | 1.000         | -                  | 0.237               | 0.763             |
| 1983          | 3   | 0.125     | 0.947        | -           | 23.2         | 0.053       | 1.000         | -                  | 0.194               | 0.806             |
| 1982          | 4   | 0.111     | 0.954        | -           | 22.9         | 0.046       | 1.000         | -                  | 0.149               | 0.851             |
| 1981          | 5   | 0.098     | 0.939        | -           | 21.5         | 0.061       | 1.000         | -                  | 0.296               | 0.704             |
| 1980          | 6   | 0.084     | 0.966        | 0.000       | 19.6         | 0.034       | 1.000         | -                  | 0.474               | 0.526             |
| 1979          | 7   | 0.075     | 0.875        | 0.097       | 17.8         | 0.028       | 1.000         | -                  | 0.655               | 0.345             |
| 1978          | 8   | 0.065     | 0.865        | 0.126       | 16.6         | 0.009       | 1.000         | -                  | 0.650               | 0.350             |
| 1977          | 9   | 0.055     | 0.838        | 0.158       | 15.5         | 0.004       | 1.000         | -                  | 0.637               | 0.343             |
| 1976          | 10  | 0.047     | 0.863        | 0.134       | 14.8         | 0.003       | 0.980         | 0.020              | 0.597               | 0.322             |
| 1975          | 11  | 0.040     | 0.869        | 0.128       | 13.8         | 0.003       | 0.919         | 0.081              | -                   | -                 |
| 1974          | 12  | 0.032     | -            | 1.000       | 12.6         | -           | -             | -                  | -                   | -                 |
| 1973          | 13  | 0.026     | -            | 1.000       | 12.9         | -           | -             | -                  | -                   | -                 |
| 1972          | 14  | 0.021     | -            | 1.000       | 13.1         | -           | -             | -                  | -                   | -                 |
| 1971          | 15  | 0.015     | -            | 1.000       | 13.2         | -           | -             | -                  | -                   | -                 |
| 1970          | 16  | 0.011     | -            | 1.000       | 13.9         | -           | -             | -                  | -                   | -                 |
| 1969          | 17  | 0.007     | -            | 1.000       | 13.9         | -           | -             | -                  | -                   | -                 |
| 1968          | 18  | 0.003     | -            | 1.000       | 13.9         | -           | -             | -                  | -                   | -                 |
| 1967          | 19  | 0.003     | -            | 1.000       | 13.9         | -           | -             | -                  | -                   | -                 |
| 1966-         | 20+ | 0.004     | -            | 1.000       | 13.9         | -           | -             | -                  | -                   | -                 |

TABLE 3-1 (cont'd)

EXAMPLE CALCULATIONS  
LIGHT-DUTY VEHICLE PARTICULATE EMISSION RATE  
LESS THAN 10 MICRONS FOR THE YEAR 1985

B. Emission Factor Component Summation Descriptions

Summation (1) calculates the emission factor component in Equations (2-3a), (2-3b), and (2-4) that are used in Equation (2-2).

Summation (2) calculates the emission factor component in Equation (2-5) that is used in Equation (2-2).

Summation (3) calculates the emission factor component in Equations (2-6), (2-7), and (2-8) that are used in Equation (2-2).

Summation (4) calculates the emission factor component in Equation (2-9) that is used in Equation (2-2).

Summation (5) calculates the emission factor component in Equation (2-10) that is used in Equation (2-2).

Summation (6) calculates the emission factor component in Equation (2-12) that is used in Equation (2-2).

Summation (7) calculates the emission factor component in Equations (2-14) and (2-15) that are used in Equation (2-2).

TABLE 3-1  
EXAMPLE CALCULATIONS  
LIGHT-DUTY VEHICLE PARTICULATE EMISSION RATE  
LESS THAN 10 MICRONS FOR THE YEAR 1985 (cont'd)

| Model<br>Year, $j$ | C. Emission Factor Component Calculations |                          |                        |                         |                        |                         |                        |
|--------------------|-------------------------------------------|--------------------------|------------------------|-------------------------|------------------------|-------------------------|------------------------|
|                    | (1)                                       | (2)                      | (3)                    | (4)                     | (5)                    | (6)                     | (7)                    |
|                    | $(EF_{1,j,k_1,1985,L})$                   | $(EF_{1,j,k_1,1985,NL})$ | $(EF_{1,j,k_2,L})$     | $(EF_{1,j,k_2,NL})$     | $(EF_{1,j,k_3,L})$     | $(EF_{1,j,k_3,NL})$     | $(EF_{1,j,D})$         |
|                    | $(F_{L,1,j})(m_{1,j})$                    | $(F_{NL,1,j})(m_{1,j})$  | $(F_{L,1,j})(m_{1,j})$ | $(F_{NL,1,j})(m_{1,j})$ | $(F_{L,1,j})(m_{1,j})$ | $(F_{NL,1,j})(m_{1,j})$ | $(F_{D,1,j})(m_{1,j})$ |
| 1985               | -                                         | 0.0001                   | -                      | 0.0007                  | -                      | 0.0004                  | 0.0008                 |
| 1984               | -                                         | 0.0004                   | -                      | 0.0025                  | -                      | 0.0017                  | 0.0026                 |
| 1983               | -                                         | 0.0004                   | -                      | 0.0022                  | -                      | 0.0016                  | 0.0020                 |
| 1982               | -                                         | 0.0003                   | -                      | 0.0020                  | -                      | 0.0015                  | 0.0015                 |
| 1981               | -                                         | 0.0003                   | -                      | 0.0017                  | -                      | 0.0011                  | 0.0018                 |
| 1980               | -                                         | 0.0003                   | -                      | 0.0015                  | -                      | 0.0008                  | 0.0020                 |
| 1979               | 0.0003                                    | 0.0003                   | -                      | 0.0012                  | -                      | 0.0005                  | 0.0015                 |
| 1978               | 0.0004                                    | 0.0002                   | 0.0001                 | 0.0011                  | 0.00001                | 0.0005                  | 0.0004                 |
| 1977               | 0.0004                                    | 0.0002                   | 0.0002                 | 0.0009                  | 0.00001                | 0.0004                  | 0.0001                 |
| 1976               | 0.0003                                    | 0.0002                   | 0.0001                 | 0.0008                  | 0.00001                | 0.0003                  | 0.0001                 |
| 1975               | 0.0003                                    | 0.0002                   | 0.0001                 | 0.0007                  | 0.00001                | 0.0003                  | 0.0001                 |
| 1974               | 0.0024                                    | -                        | 0.0014                 | -                       | 0.00003                | -                       | -                      |
| 1973               | 0.0019                                    | -                        | 0.0011                 | -                       | 0.00003                | -                       | -                      |
| 1972               | 0.0015                                    | -                        | 0.0009                 | -                       | 0.00002                | -                       | -                      |
| 1971               | 0.0010                                    | -                        | 0.0007                 | -                       | 0.00002                | -                       | -                      |
| 1970               | 0.0007                                    | -                        | 0.0004                 | -                       | 0.00001                | -                       | -                      |
| 1969               | 0.0005                                    | -                        | 0.0003                 | -                       | 0.00001                | -                       | -                      |
| 1968               | 0.0002                                    | -                        | 0.0004                 | -                       | 0.00000                | -                       | -                      |
| 1967               | 0.0002                                    | -                        | 0.0004                 | -                       | 0.00000                | -                       | -                      |
| 1966-              | 0.0003                                    | -                        | 0.0005                 | -                       | 0.00000                | -                       | -                      |
| SUM:               | 0.0104                                    | 0.0029                   | 0.0074                 | 0.0153                  | 0.00017                | 0.0091                  | 0.0129                 |

$$= .0581 \text{ (g/mile)} = EF_{1,1985,19.6}$$

## REFERENCES

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TABLE A-1  
AVERAGE ANNUAL MILEAGE BY VINTAGE FOR HEAVY-DUTY TRUCKS

| <u>Age</u> | <u>Class<br/>2-B</u> | <u>Light<br/>HDDV</u> | <u>Medium<br/>HDDV</u> | <u>Heavy<br/>HDDV</u> |
|------------|----------------------|-----------------------|------------------------|-----------------------|
| 1          | 18,352               | 45,544                | 53,370                 | 82,288                |
| 2          | 16,946               | 39,671                | 46,901                 | 74,984                |
| 3          | 15,648               | 34,558                | 41,190                 | 68,328                |
| 4          | 14,449               | 30,092                | 36,206                 | 62,263                |
| 5          | 13,342               | 26,213                | 31,812                 | 56,737                |
| 6          | 12,320               | 22,834                | 27,948                 | 51,700                |
| 7          | 11,376               | 19,898                | 24,556                 | 47,111                |
| 8          | 10,504               | 17,332                | 21,575                 | 42,930                |
| 9          | 9,700                | 15,098                | 18,956                 | 39,119                |
| 10         | 8,956                | 13,152                | 16,655                 | 35,647                |
| 11         | 8,270                | 11,456                | 14,632                 | 32,483                |
| 12         | 7,637                | 9,979                 | 12,856                 | 29,599                |
| 13         | 7,052                | 8,693                 | 11,296                 | 26,972                |
| 14         | 6,511                | 7,572                 | 9,925                  | 24,578                |
| 15         | 6,012                | 6,596                 | 8,719                  | 22,396                |
| 16         | 5,552                | 5,746                 | 7,661                  | 20,408                |
| 17         | 5,126                | 5,005                 | 6,728                  | 18,597                |
| 18         | 4,734                | 4,360                 | 5,913                  | 16,946                |
| 19         | 4,371                | 3,798                 | 5,196                  | 15,442                |
| 20+        | 4,036                | 3,308                 | 4,565                  | 14,071                |

Source: MOBILE3.

TABLE A-2  
PROJECTIONS OF HEAVY-DUTY VEHICLES IN OPERATION

| <u>Year</u> | <u>Class<br/>2-B</u> | <u>Light<br/>HDDV</u> | <u>Medium<br/>HDDV</u> | <u>Heavy<br/>HDDV</u> |
|-------------|----------------------|-----------------------|------------------------|-----------------------|
| 1980        | 0.000                | 0.006                 | 0.112                  | 1.521                 |
| 1981        | 0.000                | 0.006                 | 0.124                  | 1.581                 |
| 1982        | 0.049                | 0.009                 | 0.135                  | 1.599                 |
| 1983        | 0.014                | 0.013                 | 0.141                  | 1.592                 |
| 1984        | 0.185                | 0.022                 | 0.153                  | 1.641                 |
| 1985        | 0.274                | 0.037                 | 0.166                  | 1.719                 |
| 1986        | 0.370                | 0.053                 | 0.177                  | 1.816                 |
| 1987        | 0.475                | 0.071                 | 0.185                  | 1.927                 |
| 1988        | 0.588                | 0.089                 | 0.193                  | 2.041                 |
| 1989        | 0.707                | 0.106                 | 0.201                  | 2.151                 |
| 1990        | 0.831                | 0.122                 | 0.208                  | 2.258                 |
| 1991        | 0.960                | 0.137                 | 0.215                  | 2.362                 |
| 1992        | 1.092                | 0.151                 | 0.222                  | 2.471                 |
| 1993        | 1.225                | 0.165                 | 0.229                  | 2.581                 |
| 1994        | 1.354                | 0.178                 | 0.237                  | 2.693                 |
| 1995        | 1.480                | 0.190                 | 0.245                  | 2.807                 |
| 1996        | 1.600                | 0.202                 | 0.253                  | 2.914                 |
| 1997        | 1.712                | 0.212                 | 0.261                  | 3.015                 |
| 1998        | 1.816                | 0.222                 | 0.269                  | 3.108                 |
| 1999        | 1.912                | 0.230                 | 0.276                  | 3.194                 |
| 2000        | 1.999                | 0.238                 | 0.283                  | 3.273                 |

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Source: MOBILE3.